ISSUE 1 • 2014

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Applications, Science, and Sustainability of Coal Ash

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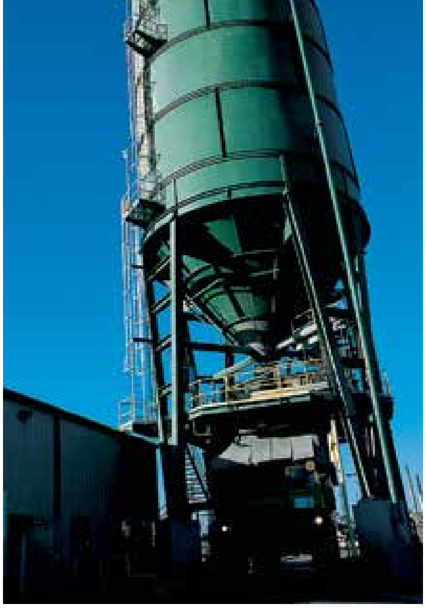

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On the Cover

Road base is just one of the myriad of coal ash uses that go Beyond Concrete.

THE NOBLE ENVIRONMENTALISTS

By Hollis Walker, ACAA Chair

Greetings to my fellow environmentalists! Many of us do not embrace that title, as it has sadly been hijacked by zealots that worship a cause rather than true stewardship (more on this in a bit). I trace my environmentalism back to my first year graduating from college. As I was able to move from a $20-per-week budget to getting a paycheck that enabled a budget-free lifestyle (at least until I became acclimated to such funds), I found myself taking up hobbies such as kayaking, mountain biking, camping, and to lesser degrees hiking and rock climbing. It was these outdoor activities that really afforded me the opportunity to absorb the splendor of God's creation. While I never believed mankind is capable of destroying the earth, I knew that he could temporarily dirty up a spot or two, and while enjoying my outdoor activities I have found myself outraged more than a few times. I think my concern for a clean environment is a pretty basic instinct, and therefore shared by a vast majority of Americans. So why does the very mention of some environmentally themed buzzwords evoke an emotional response with me and many, if not a majority, of our citizenry?

This common decency shared by so many people has been hijacked into a big business. It's simply the corporatization of environmental stewardship. The large environmental nongovernmental organizations (ENGOs) have become a big industry with high salaries and power players that push around farmers, corporations, and governmental bodies. While their power and numbers have grown over the decades, their substantive impact to the environment has waned. With giant leaps made in pollution control as a result of environmental laws of the 1970s, real substantive change in the quality of our environment has been achieved.

As these changes occurred over the years the playing field for substantive potential action on the environment became smaller, while at the same time, more and more environmental organizations formed. Just like any industry in a free market, the law of supply and demand will manifest itself in some way, and with a low supply (fewer real environmental issues) and high demand (groups looking to fix the environment), there had to be a breaking point. And what broke was integrity. The loss of integrity has become so saturated in the ENGO community that many have lost any shame about being untruthful, and moved from distorting facts to outright lies complete with sophisticated propaganda campaigns completely based on falsehoods.

For most of us in the fossil industry, we have long seen the dishonesty and have felt the frustration that the ENGO's dishonesty hasn't been more evident to the average American. We can study the pages and pages of so-called coal ash "damage cases" published by the ENGOs, then review the responses to such allegations as reported by Electroic Power Research Institute (EPRI), and clearly see the dishonesty of the ENGOs. However, conveying that volume of information simply is not feasible to the average American, particularly in today's sound-bite information age.

The good news is that I don't think it's all on us. The power of the ENGOs has so greatly influenced governmental policy (and for such meaningless improvement) at every level—federal, state, county, and city—that the average American is starting to feel the pinch and relying on their own common sense that there has been no substantive improvement in their surroundings, yet they feel a cost (think: there are no 100 watt lightbulbs around).

While this may sound like a rant against ENGOs, it's really not that but rather a reality check for us all. The ENGOs, whether through media outlets or the lobbying of environmental agencies, have been the greatest threat and impediment to the reuse of Coal Compustion Products (CCPs). In simple laymen terms, the ENGOs fight against recycling. Let that sink in for a moment. And with the science (and when I say "science" I mean taking measurements—not theoretical algorithms loaded with assumptions that are debatable) so one-sided in favor of reuse of CCPs, it's not even a fair debate amongst honest participants.

While the the ENGOs are doing the heavy lifting of exposing their dishonesty by themselves, I think our role is to help facilitate this exposure by each of us committing a few facts to memory and articulating them as often as chance permits. So this is a call to the CCP industry to arm themselves with the facts (truth), participate in debate, call out those who distort truth, and be proud that you are noble environmentalists—one who promotes reusing what others would have squandered, helping offset extraction of needed resources that improve the human condition, and reducing energy consumption from mining.

A consent decree in a federal district court in Washington, DC, calls for the U.S. Environmental Protection Agency (EPA) to submit a regulation by December 19. The EPA has signaled that it is trending toward a Subtitle D CCR rule (that is, nonhazardous). While this appears to provide relief to the primary concern of ACAA members that hazardous waste regulation of any form is off the table, the devil is often in the details. Even with a favorable Subtitle D rule from the EPA, we will not be able to let our guard down as recent activities in North Carolina have shown. So spend some time visiting our website and commit some facts to memory. Remember my fellow environmentalists: truth will prevail. Knowledge up! ❖

CAROLINA ON MY MIND

By Thomas H. Adams, ACAA Executive Director

The ACAA has been focused on the effort to create coal ash regulations in Washington, DC, for almost 6 years now. Following the December 22, 2008, Kingston, TN, ash spill, the federal government decided to revisit a task they had not been able to complete since the passage of the Bevill Amendment in 1980. With a new, friendly administration in the White House, a majority of congressional seats, and a new administrator at the U.S. Environmental Protection Agency (EPA), anti-coal interests knew the planets were aligned to deliver them to the Promised Land. Because of the hard work of ACAA members and many, many other organizations and interests, the trip to paradise has been seemingly parked at a rest stop. Indications are that the EPA is inclined to regulate coal ash disposal under Subtitle D of the Resource Conservation and Recovery Act of 1976. Subtitle D regulation removes the threat posed by any form of hazardous waste regulation.

Just as the light at the end of the federal tunnel start to shine ever so slightly, a spill at the Dan River plant in North Carolina happened in February 2014. The ENGOs were re-energized as they now had fresh evidence that state regulation of coal ash disposal was not protective of human health and the environment. After the spill, a media frenzy was unleashed. Our office was deluged with requests for comments from both local and national media. Most of the media had already been tutored by the anti-coal crowd. Disabusing media of their education from the activists was difficult. The ACAA's comments were limited to the nature of the materials and the opportunities for beneficial use.

Complicating the situation is the fact that North Carolina Governor Pat McCrory had over 20 years of employment at Duke Energy. ENGOs tried to make the case that the governor had not acted on coal ash ponds due to his past history with the utility. While this makes great theater, there is no evidence to support the allegation.

Duke Energy has a number of ash ponds in North Carolina. ENGOs have attempted to persuade the citizens that all of these ponds are ticking time bombs. To calm the waters (no pun intended), the governor and legislature began to work on a bill to address the ash pond issue. On August 19, the legislature passed a bill to address the ash pond issue. The governor allowed this bill to become law on September 20 without his signature. Governor McCrory was not supportive of the provisions for the creation of an ash commission to handle implementation required by the bill. The new law has an aggressive time line for several items. It also has language which should benefit the recycling of coal combustion products. The nine ash commission members have been appointed. Three members were appointed by the governor, three by the President Pro-Tempore of the Senate, and three by the Speaker of the House. The ACAA submitted the names of two North Carolina residents highly qualified to speak on beneficial use. Lisa Cooper, Senior Vice President of PMI Ash Technologies, Cary, NC, and Cecil Jones, retired Chief Materials Engineer from the North Carolina Department of Transportation from Raleigh were suggested for an appointment to ensure knowledgeable input to the commission deliberations as it considers how best to handle the future of ash ponds. We were unsuccessful in getting the ACAA nominees appointed. They remain available to provide input to the commission as the opportunity presents itself. We thank Lisa and Cecil for their willingness to stand for appointment.

North Carolina is the focus of attention for those interested in ash ponds. Whatever this state does will impact the actions of other states with ash ponds. The ACAA will closely monitor developments in North Carolina and seize upon opportunities to protect and advance beneficial use. Plainly stated, the ACAA position is that the solution to the ash pond issue does not lie exclusively with new, improved disposal techniques. Some of the ponded ash can and should be directed to beneficial use. So, Carolina will be on my mind for the foreseeable future. I am sure it will be on yours as well. ❖

ASH BILL BECOMES LAW IN NORTH CAROLINA

Following the February 2014 ash spill from a pond at Duke Energy's Dan River facility, Governor Pat McCrory and the state legislature moved to create legislation to closely manage ash ponds in North Carolina. The Coal Ash Management Act of 2014 became law on September 20, 2014. A complete copy of the bill is available at **http://legiscan.com/NC/text/S729/2013**.

An important feature of the new law is the creation of a Coal Ash Management Commission (CAMC). The nine-member commission is charged with implementation of the provisions of the act as North Carolina evaluates 33 ash ponds. The Governor, President Pro Tempore of the Senate, and Speaker of the House were each allocated three appointments to the commission subject to specific qualifications. In an unusual twist, the CAMC will have oversight from the Department of Public Safety, not the Department of Energy and Natural Resources (DENR).

Political intrigue was injected immediately after the spill due to Governor McCrory's years of employment by Duke Energy. The governor was accused of allowing Duke Energy to ignore the dangers posed by the ash ponds. A grand jury continues to probe the relations between the DENR and the utility.

Developments in North Carolina are expected to set standards for other states that have coal ash ponds.

ASTM ACTION

ASTM International held a series of meetings recently in New Orleans, LA. Committee E50, Environmental Assessment, Risk Management and Corrective Action, and E60, Sustainability, as well as their related subcommittees, met with ACAA. Focus for this meeting was on Subcommittee E50.03, Pollution Prevention/Beneficial Use. Gwen Eklund is the Chair of E50.03. This subcommittee recently completed work on E2277, "Standard Guide for Design and Construction of Structural Fills," an effort that took almost 3 years to complete. This allowed the members to focus on other items on their "to-do" list.

First up for consideration was E2060, "Standard Guide for Use of Coal Combustion Products for Solidification/Stabilization of Inorganic Wastes." This standard was last approved in 2006. According to ASTM rules, the standard must be reapproved this year or be removed from the inventory of active documents. The subcommittee discussed the document and came to the consensus that it was still relevant and useful but needed some updates. To prevent the document from falling off the document inventory, the subcommittee decided to put out a ballot with a deadline prior to the end of the year. This action would keep the document active even if negative votes were received. Following resolution and approval, the subcommittee would then take on the task of updating the text. Kimery Vories, recently retired from the Office of Surface Mining, reminded the subcommittee of the value of documents such as E2060 to the regulatory process. Regulators rely on the reports of independent third parties such as ASTM International in rulemaking.

The subcommittee also expressed interest in two proposed projects. To bring some continuity to the risk assessment of coal combustion products (CCPs), the subcommittee will form a task group to create a guide to risk assessment of CCP. A Chair is needed for this work. The second project of interest was proposed by Ray Bryant, USDA Agricultural Research Service, and Ann Couwenhoven, Raven Energy. It was proposed that ASTM International create a guide on the beneficial use of flue gas desulfurization gypsum as a soil amendment. Again, a task group leader is needed. It is expected that work on these two documents will commence in early 2015.

EUROCOALASH 2014

The European coal ash community met for a workshop on October 14 and 15 in Munich, Germany. The event attracted 79 participants from 21 countries from around Europe and beyond. The event was hosted by VGB PowerTech and co-organized by ECOBA (European Coal Combustion Products Association) and the CBM of the Technical University Munich. Topics covered in the 29 presentations included sustainable use of CCP; developments in EU cement standards; sustainable masonry products made with CCP; life-cycle analysis of masonry made with CCP; challenges in using ash from lignite coal combustion; alkali-activated binders; leaching of dangerous substances from construction products; potential for use of stockpiled ash; and beneficiation of landfilled ash. Several updates were provided on regulatory developments across the globe. ACAA Executive Director Thomas Adams provided a presentation on the current state of federal regulations in the United States, along with the recent developments in North Carolina.

ECOBA hosted a Research Workshop on October 13 just prior to the start of EUROCOALASH. This 1-day event featured invited research papers on CCP.

At the conclusion of this workshop, Joachim Fuerborn, Secretary General of ECOBA, announced that EUROCOALASH 2016 will be held in the Czech Republic.

WOCA 2015 COMES TO MUSIC CITY

North America's premier coal ash conference and exhibition comes to Nashville, TN, on May 4-7, 2015. Co-hosted by the Center for Applied Energy Research at the University of Kentucky and the ACAA, World of Coal Ash (WOCA) provides a forum for technical presentations on a broad spectrum of topics related to coal combustion products (CCPs). In addition to over 100 technical presentations, the exhibit hall offers attendees the opportunity to meet over 50 of the most progressive vendors of equipment and services for CCP management and beneficial use. The event is expected to attract over 500 attendees from around the globe.

For those who desire an intensive educational experience, a short course will be held on Monday, May 4. The course covers the science and technology of CCPs taught by experts from academia and industry.

The Renaissance Hotel in downtown Nashville is the official hotel for WOCA 2015. It is conveniently located near the vibrant clubs and restaurants that have made Nashville famous. No visit to Nashville is complete without a visit to the Ryman Auditorium, known as the "Mother Church of Country Music." The Ryman is located one block from the Renaissance Hotel. The Country Music Hall of Fame and Museum is close by as well. Nashville is home to many other points of interest, including Vanderbilt University, the Hermitage, and the Grand Ole Opry.

For more information on WOCA 2015, visit the event website at **www.worldofcoalash.org**.


Charah

A WORLD OF BENEFICIAL USES

Myriad of Applications Safely and Productively Use Coal Combustion Products

By John Ward

In the 1970s and 1980s, a popular marketing tactic called for listing all of the places an industry's product was used. Sometime around then, the coal ash beneficial use industry decided not to be outdone and published a long list that included, among other things, toothpaste and bowling balls.

Fast-forward a generation to the 2010s, when a host of anti-coal environmental groups began aggressively attacking the "dangers" of coal ash. "The EPA wants to classify coal ash as hazardous waste—and you can find it in your home, backyard, and medicine cabinet," warned *Mother Jones* magazine. Panicked readers began asking which brands of toothpaste to avoid.

Set aside for a moment the fact that the U.S. Environmental Protection Agency (EPA) is now signaling that it will not pursue its ill-conceived "hazardous waste" proposal. Also set aside that if there ever really was coal ash in toothpaste, it hasn't been there in decades. (Whether ash still makes its way into bowling balls is a matter of some speculation, but clearly it doesn't happen in volumes large enough to be reported as a major use.) The point is that *Mother Jones* is essentially correct: Coal ash is a valuable ingredient in dozens of products and applications that surround us in everyday life. What *Mother Jones* doesn't get is this: That's a good thing.

TWO SIDES OF THE COAL ASH COIN: PRODUCTION AND USE

Since the early 1960s, the ACAA has conducted an annual survey of utilities to determine the volumes of coal ash that are produced and used in various applications. A few major trends are evident in this trove of data (Fig. 1).

First, there is a lot more coal ash produced today than in previous decades. This is partly because America is consuming more coal and partly because steadily increasing emissions controls result in more material being collected. (This is especially the case with flue gas desulfurization materials, also known as synthetic gypsum. A by-product of the scrubbers used to remove sulfur from power plant emissions, these materials are not really "ash," but are managed and regulated alongside coal ash—hence their inclusion in the family of coal combustion products.)

Second, the beneficial use of coal ash has increased steadily over time and has grown most dramatically during periods of regulatory certainty. (Usage rates increased almost 50% between 2000 and 2008—the period in which EPA's "Final Regulatory Determination" that coal ash did not warrant hazardous waste regulation was in place.)

And third, any coal ash that is not used has to go somewhere. That "somewhere" is landfills and wet impoundments which are the primary focus of concerns over ash handling and safety. The best solution to coal ash disposal problems would be to quit throwing coal ash away. But continuing regulatory uncertainty and negative publicity by anti-coal activists have the

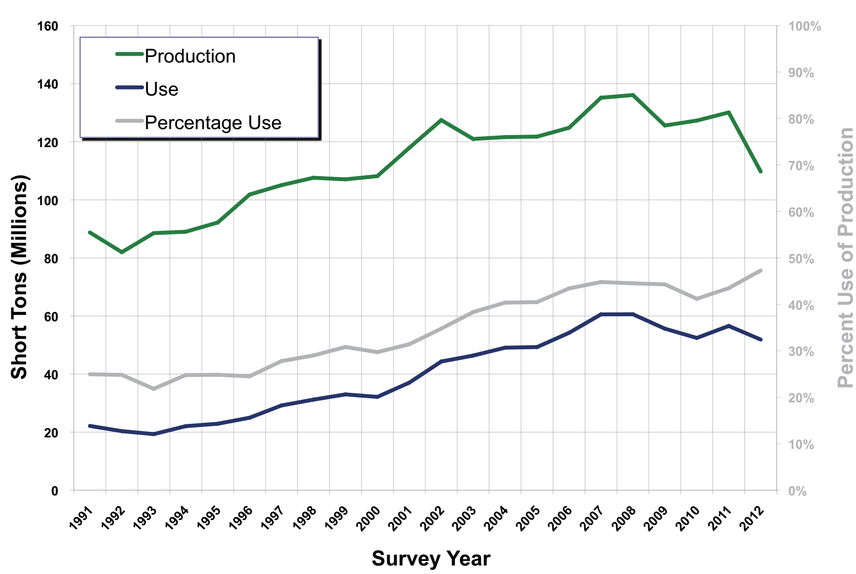
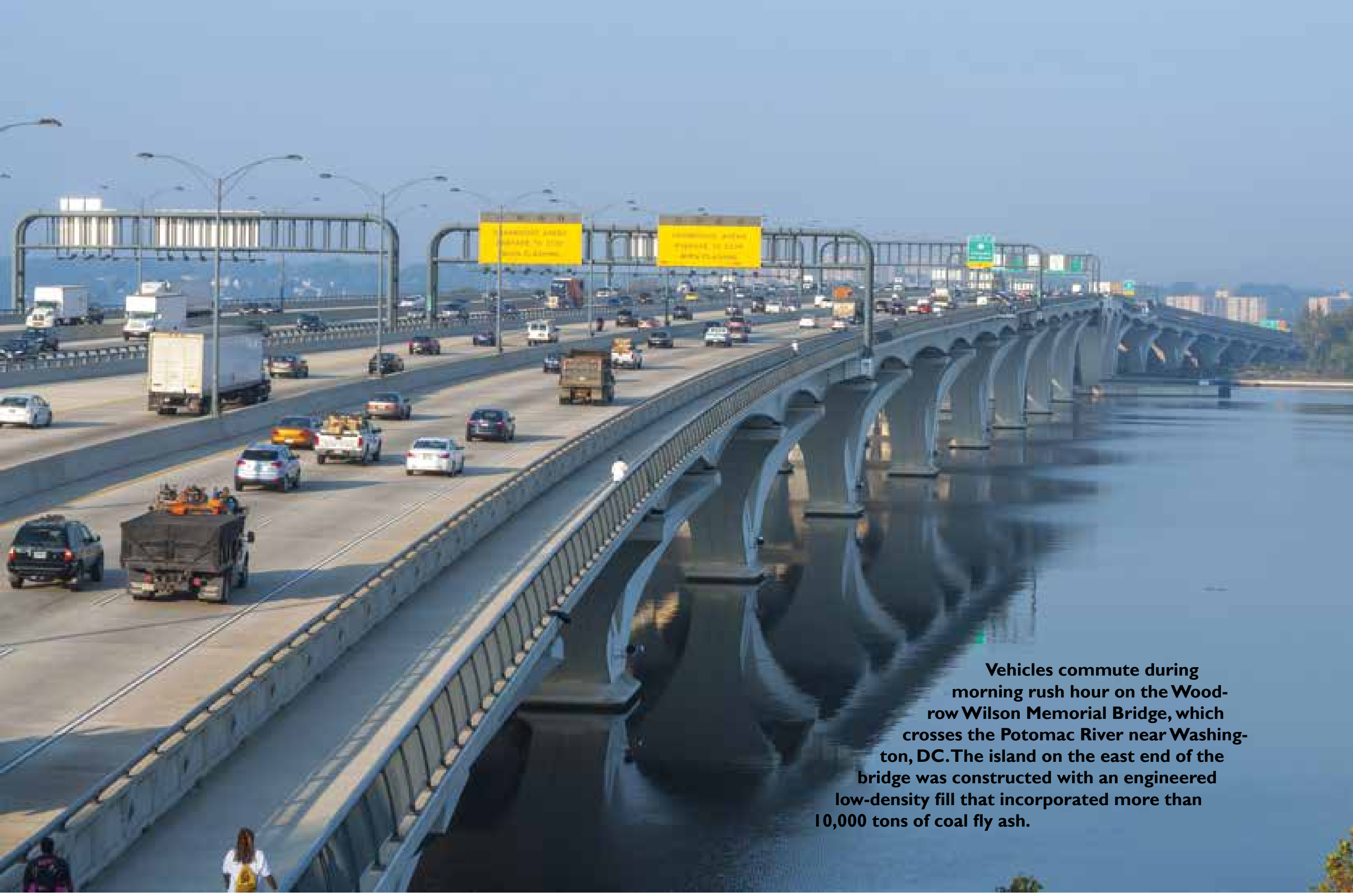


Fig. 1: CCP production and use, 1990 to 2012



Vehicles commute during morning rush hour on the Woodrow Wilson Memorial Bridge, which crosses the Potomac River near Washington, DC. The island on the east end of the bridge was constructed with an engineered low-density fill that incorporated more than 10,000 tons of coal fly ash.

perverse effect of causing more ash to be disposed. If the United States had just kept volume usage level with 2008 over the next 4 years, then 25.9 million fewer tons of coal ash would have been disposed of in landfills and impoundments.

AN ARRAY OF BENEFICIAL USES FROM WHICH TO CHOOSE

A look at the most recently available ACAA Production and Use Report provides a glimpse of the wide variety of uses that are available (Fig. 2).

The most well-known beneficial uses also account for the most volume. During 2012, 11.8 million tons of coal fly ash were used in concrete and 7.6 million tons of synthetic gypsum were used in manufacturing wallboard. Those uses are second only to the use of coal ash in mine reclamation, which accounted for 12.8 million tons of use.

But coal ash is also frequently used as a road base material or for stabilizing soils for roads and parking lots. In these

EPA WIELDS BLUNT INSTRUMENT IN ATTEMPT TO CLASSIFY BENEFICIAL USE

From 2002 until 2010, the EPA spearheaded the Coal Combustion Products Partnership ("C2P2" program)—a highly successful collaboration between several federal agencies and industry to promote increased beneficial use of coal ash. Anti-coal environmental groups complained to the EPA's Inspector General that the Agency was "too cozy" with industry and an investigation ensued. The EPA abruptly and unilaterally canceled C2P2. Then, after nearly a million dollars of investigation, the Inspector General concluded that the EPA should do more to evaluate risks of beneficial use if (emphasis on "if") the Agency was going to actively promote the practices.

Despite the fact that the EPA has shown little or no interest in actively promoting coal ash beneficial use since 2010, the Agency did embark on an activity to create "Beneficial Use Risk Evaluation Methodologies." The first methodology (for "encapsulated" uses) was released in February 2014 along with the application of the methodology to two major uses—fly ash concrete and synthetic gypsum wallboard. (Both passed with flying colors.) The Agency is currently working to develop a second methodology for "unencapsulated" uses.

Lost in this bureaucratic inertia is the fact that the terms "encapsulated" and "unencapsulated" are relatively new and poorly defined. The terms were not used in the C2P2 program or in any EPA regulatory activity prior to 2010. Nor are they the product of any public or academic discussion regarding what they should mean or whether, in fact, a distinction is even warranted.

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2012 Coal Combustion Product (CCP) Production & Use Survey Report

Beneficial Utilization versus Production Totals (Short Tons)									
2012 CCP Categories	Fly Ash**	Bottom Ash**	Boiler Slag*	FGD Gypsum**	FGD Material Wet Scrubbers*	FGD Material Dry Scrubbers*	FGD Other*	FBC Ash*	CCP Production / Utilization Totals
Total CCPs Produced by Category	**52,100,000**	**14,100,000**	**1,720,945**	**24,200,000**	**6,803,636**	**655,119**	**326,762**	**9,843,922**	109,750,384
Total CCPs Used by Category	**23,205,204**	**5,474,167**	**1,437,556**	**12,102,964**	**546,616**	**205,733**	**0**	**8,914,774**	**51,887,014**
1. Concrete/Concrete Products /Grout	11,779,021	732,260	0	63,607	0	5,372	0	0	**12,580,260**
2. Blended Cement/ Feed for Clinker	2,281,211	1,287,343	0	1,755,891	0	0	0	0	**5,324,445**
3. Flowable Fill	141,081	9,435	0	0	0	28	0	0	**150,544**
4. Structural Fills/Embankments	3,083,441	1,716,196	210,000	6,738	321,676	65,065	0	0	**5,403,116**
5. Road Base/Sub-base	193,711	352,469	1,300	31	0	0	0	0	**547,511**
6. Soil Modification/Stabilization	303,354	140,092	0	1,425	0	821	0	64,562	**510,254**
7. Snow and Ice Control	0	198,153	57,975	0	0	0	0	0	**256,128**
8. Blasting Grit/Roofing Granules	11,678	15,930	1,156,246	0	0	0	0	0	**1,183,854**
9. Mining Applications	2,086,074	437,986	0	1,181,799	224,940	118,868	0	8,762,464	**12,812,131**
10. Gypsum Panel Products	0	0	0	7,641,625	0	0	0	0	**7,641,625**
11. Waste Stabilization/Solidification	2,187,514	333	0	777,479	0	227	0	87,748	**3,053,301**
12. Agriculture	26,312	1,698	0	655,600	0	0	0	0	**683,610**
13. Aggregate	0	381,657	12,035	0	0	0	0	0	**393,692**
14. Oil Field Services	568,772	18,215	0	0	0	15,352	0	0	**602,339**
15. Miscellaneous/Other	543,035	182,400	0	18,769	0	0	0	0	**744,204**
Summary Utilization to Production Rate									
CCP Categories	Fly Ash	Bottom Ash	Boiler Slag	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers	FGD Other	FBC Ash	CCP Utilization Total**
Totals by CCP Type/Application	23,205,204	5,474,167	1,437,556	12,102,964	546,616	205,733	0	8,914,774	**51,887,014**
Category Use to Production Rate (%)***	44.53%	38.82%	83.53%	50.00%	8.03%	31.40%	0.00%	90.56%	**47.27%**
2012 Cenospheres Sold (Pounds)	**23,104,970**	This data represents 209, 598 MWs Name Plate rating of the total industry wide approximate 329,483 MW capacity (coal fueled) based on Ventyx data							

The data received this year represents approximately 59 % of the coal consumed in 2012 by electric utilites and IPPs (approximately 821,400,000 tons)

* These are actual tonnages reported by utilities responding and **do not reflect estimates for utilities that did not respond** this year.

**These numbers are derived from previous, current and applicable industry-wide available data, including Energy Information Administration (EIA) Reports 923 and 860 and other outside sources.

***Utilization estimates are based on actual tons reported and on **extrapolated estimates only for fly ash, bottom ash, and FGD gypsum**;

Fig. 2: 2012 CCP Production and Use Survey report

applications, coal ash eliminates the need to quarry other materials or use products such as cement and lime that are energy-intensive to manufacture.

An application of growing importance is the use of synthetic gypsum from power plants for agriculture. Fields treated with gypsum have improved soil quality and retain water better. This creates higher crop yields and prevents the runoff of fertilizers and other agrochemicals that can damage waterways downstream.

Coal ash is used in a variety of manufactured building products, such as concrete masonry units, asphalt shingles, carpet backing, and even plastic-based trimboards.

Using coal ash as structural fill is also appropriate when proper engineering controls are in place. An ASTM International standard guide sets out best practices for engineers using this material and many states have implemented programs for overseeing the proper construction of structural fills. It's important to remember that coal ash is often specified for engineered fill activities because of its unique mechanical properties that can be superior to locally quarried materials in many locations.

PROTECTING HEALTH AND ENVIRONMENT

Attacks on coal ash—either in disposal or beneficial use settings—invariably start with a laundry list of "what's in it." Activists trot out a litany of scary-sounding metals and claim ash is "laden" with "toxins." In truth, the trace levels of metals in coal ash are comparable to the levels of metals in the materials coal ash replaces when used beneficially. (See *ASH at Work* Issue 1 2012, "Coal Ash Material Safety: Analysis of New Federal Government Data Shows Coal Ash Comparable to Residential Soils.")

The question for considering coal ash safety shouldn't be "What's in the ash?" If the objective is protecting human health and the environment, that question is superficial and irrelevant. Almost everything around us has heavy metals in it. Those fancy new lightbulbs have much greater concentrations of mercury than coal ash, and daily multivitamin pills probably contain selenium and chromium, among other things.

A better question to ask about the health and environmental safety of any material is "Can what's in it get out and find its way into people in quantities sufficient to cause harm?"

In February 2014, the EPA released the results of an exhaustive evaluation of the risks of using coal fly ash in concrete and synthetic gypsum in wallboard (see sidebar, "EPA Wields Blunt Instrument in Attempt to Classify Beneficial Use"). EPA evaluators concluded that "…[e]nvironmental releases of constituents of potential concern (COPCs) from CCR fly ash concrete and FGD gypsum wallboard during use by the consumer are comparable to or lower than those from analogous non-CCR products, or are at or below relevant regulatory and health-based benchmarks for human and ecological receptors. EPA supports the beneficial use of coal fly ash in concrete and FGD gypsum in wallboard. The Agency believes that these beneficial uses provide significant

Mark your calendar for:

Winter Membership Meeting— February 10 and 11, 2015

Did you know that Savannah, GA, is the largest National Historic Landmark District in the United States? Founded in 1733, the city has a rich historic legacy and provides visitors with an opportunity to look back at the people and places that made Savannah an important part of U.S. history. Following the American Revolution, it was the southernmost city of the new country for many years. During the Civil War, Savannah was the primary target of General William T. Sherman in his famous March to the Sea. Located on the banks of the Savannah River and about 20 miles from the Atlantic Ocean, the Port of Savannah has long been one of the most important ports in the United States. Agriculture and manufacturing are the other economic drivers in the regional economy.

The American Coal Ash Association will hold its Winter Membership Meeting in Savannah on February 10 and 11, 2015. The meeting format will be similar to recent meetings, with committee meetings being held on the first day and technical presentations on the second day. The Women's Leadership Forum will meet on February 10. A welcome reception will close the first day's activities.

Take a break from the winter weather and join us in Savannah on February 10 and 11. For more information, visit the ACAA website, www.acaa-usa.org.

ASTM INTERNATIONAL PROVIDES GUIDANCE ON STRUCTURAL FILLS

Beneficially using coal ash in structural fill activities involves a lot more than just dumping ash into low spots. Proper controls are required to ensure that the ash accomplishes both engineering and environmental objectives.

The international standards-setting body ASTM International has published guidance to help accomplish this. ASTM E2277-14, "Standard Guide for Design and Construction of Coal Ash Structural Fills," covers procedures for the design and construction of engineered structural fills using coal combustion products (CCPs) including but not limited to fly ash, bottom ash, boiler slag, or other CCPs that can meet the requirements of an engineered fill.

ASTM standards are in addition to laws and regulations imposed on coal ash use by many state departments of environmental protection. These best practices and regulations are the result of decades of experience successfully using coal ash for structural fill activities.

opportunities to advance Sustainable Materials Management (SMM)."

In conducting this study, EPA subjected products containing coal ash to a broad spectrum of conditions, including many that are unlikely to occur in real life. (The products containing coal ash still passed with flying colors.) But one thing the EPA study absolutely got right was looking beyond the simplistic question of "what's in it."

COMPARISON—THE PROPER PARADIGM FOR EVALUATING USES

When the EPA evaluated two prominent beneficial uses of coal ash, the Agency asked the best question: How does a product containing ash compare to the same product made without it? If the product containing coal ash performs at least as safely as the product that doesn't, then why shouldn't we encourage uses that keep coal ash out of landfills and disposal ponds where health and environmental risks are greater?

Using comparison as an evaluation tool can work for any product. Consider the toothpaste example. If toothpaste containing coal ash resulted in the same or less exposure to metals than toothpaste without coal ash, what would be the problem? Millions of people have mercury permanently installed in their mouths as part of dental fillings. It's safe because the mercury is in a form that doesn't get out of the fillings and into people.

While toothpaste is currently only a hypothetical example, there are other active beneficial uses that are coming under increased scrutiny. An example is the use of bottom ash as a deicing agent for roads. Bottom ash is a coarse, granular product less subject to leaching of trace metals. Because it is dark in color, many communities find it to be an effective material for controlling snow and ice in the winter. Any evaluation of this use would be short-sighted if it only considers what is contained in the ash. Evaluation should first determine whether constituents of the ash actually leach out during normal use. Then the evaluation should compare those results to the environmental performance of alternative materials. Salts and sands that are also used for traction control are hardly environmentally benign.

Another common beneficial use that is receiving increased attention is the use of coal ash for structural fills. A glance at this magazine's "Ash Classics" feature shows people have been applying sound engineering practices to the use of coal ash in structural fills for longer than many of our readers have been alive. The notable lack of environmental damage cases related to these projects after decades of widespread use is one indication of their safety. The presence of industry standards to guide their proper installation (see sidebar, "ASTM International Provides Guidance on Structural Fills") gives added assurance that future projects can be constructed in a manner that effectively prevents trace metals contained in coal ash from presenting any threat to human health or the environment.

ONE MORE QUESTION TO ASK

It is also fair to ask why coal ash is being singled out for this level of scrutiny in the first place. Is it because it has "coal" in its name?

The complaints that led to the EPA developing "risk evaluation methodologies" for coal ash came from environmental groups dedicated to the elimination of coal as an energy resource. The conclusion of the EPA's Inspector General who investigated those complaints was that the EPA should evaluate risks before deciding whether to promote or publicly support a practice. The Inspector General did not conclude that coal ash was somehow inherently dangerous—just that the Agency should do more to evaluate uses before endorsing them.

If opponents of coal are truly concerned about the contents of building materials, where is the outcry calling for detailed examination of the environmental performance of materials coal ash replaces when it is used?

Despite vigorous opposition to coal as an energy source, it will continue to account for the largest portion of our electricity supply for decades to come. That means we will continue to generate tens of millions of tons of coal ash each year in addition to the challenge of closing and cleaning up historic disposal sites. Human health and the environment will benefit if environmental activists and policymakers refocus efforts on using coal ash beneficially rather than just throwing it away. Of course, that requires thoughtful consideration extending beyond the simple demonization of all things related to "coal." ❖

About the Author: John Ward is President of John Ward, Inc., an energy consultancy specializing in coal-related issues. He serves as Chairman of the American Coal Ash Association's Government Relations Committee and of the ash marketing activist group Citizens for Recycling First.

TECHNICAL CONSIDERATIONS FOR BENEFICIAL USE OF COAL ASH IN CIVIL ENGINEERING APPLICATIONS

By Veronica E. Foster, P.E., and Robert S. Valorio, P.E.

A number of states have statutory targets for waste reduction within their borders. The beneficial use of residual wastes (that is, wastes which are the by-product of a manufacturing process) has been a common practice in the United States for more than 80 years. This practice has fluctuated with the country's economic performance. Reuse and recycling strategies to reduce costs of raw materials for products or to solve some other problem have developed as budgets decreased and competition increased.

The range of potential beneficial uses for coal combustion by-products were discussed by the United States Environmental Protection Agency (U.S. EPA) in the preamble to the proposed Coal Combustion Residuals (CCR) Rule issued in June 2010. The potential beneficial uses listed in the preamble of the proposed CCR Rule included the following:

- Construction applications: brick, cement, concrete, road bed, structural fill, blast grit, wallboard, insulation, and roofing materials;
- Waste stabilization;
- Agricultural applications; and
- Other applications: absorbents, filter media, paints, snow/ice control, and plastics/metal manufacture.

The long-awaited final CCR Rule is anticipated to be issued by the U.S. EPA in December 2014.

Commensurate with the proposed CCR Rule, the U.S. EPA developed a methodology for evaluating CCR in consideration of the risk to human health and the environment associated with the potential beneficial use. As recently as February 2014, the U.S. EPA used this methodology to reaffirm its support of the beneficial use of coal fly ash in concrete and flue-gas desulfurization (FGD) gypsum in wallboard.

The potential beneficial use of CCR for other applications requires considerations that include:

- Risk to human health and the environment evaluated using the U.S. EPA-established criteria;
- Cost savings;
- Environmental liability;
- Public relations challenges;
- Sufficient supply of suitable CCR; and
- Suitability, homogeneity, and consistency of the available CCR.

The first five bullet items in the aforementioned list can be addressed by the general beneficial use evaluation conducted by the company considering CCR as a raw material replacement and will not be discussed further in this article. The focus of this article is limited to the sixth bullet—the available CCR suitable for the potential beneficial use in terms of both chemical and physical properties—and whether or not those properties are homogenous and consistent, especially when compared with the homogeneity and consistency of the raw material that may be replaced by the CCR.

Coal-fired power plants typically use multiple sources for the coal they burn. Coal from a combination of sources may be burned simultaneously, or the plant may use one source for a period and then change to another. It is important to understand that coal from different sources produces CCR with differing resulting chemistry. For example, it has been Golder's experience that coal from eastern Kentucky can have high (>55%) silicon dioxide composition and low (<0.5%) sodium oxide, while coal from North Dakota can have low (≤20%) silicon dioxide composition and high (>6.0%) sodium oxide. Therefore, if such variability in chemical composition can impact the quality of the product for which beneficial use is being considered, it is imperative to understand the variability of the coal sources used by the CCR supplier. It is also important to understand that there can be variability of coal within the same coal seam, resulting in a potential for variability in chemical composition from a single coal source. Consequently, routine analytical testing of the beneficial use of CCR may be prudent to ensure consistency of the finished product where large variability in chemical composition directly impacts product quality.

As with chemical composition, the physical properties of coal ash can change from one coal source to another and within the same coal source. Routine testing of the beneficial use of CCR may again be prudent if changes in the physical properties will result in an inconsistent finished product or a finished product that does not meet quality requirements. The following table provides a range of physical properties based on the testing of fly ash by ASTM International Standard Methods at one of Golder's geotechnical testing laboratories for five civil engineering projects located along the East Coast of the United States.

Potential civil engineering applications for coal ash material for beneficial use could include the following:

- Subgrade fill beneath paved roadways;
- Daily cover at solid waste landfills, where permissible;
- Subgrade fill beneath landfill liner systems; and
- Controlled low-strength material (flowable fill).

The variation in chemical properties is often more tolerable provided that risk thresholds are not exceeded for human health or the environment or where such variation could affect an associated product (for example, coal ash used as fill against a concrete foundation). However, variation in the physical properties, or more specifically, variation in the engineering properties of the coal ash, is much less tolerable. To evaluate the beneficial use of coal ash in civil engineering applications, an understanding of the engineering properties of the raw material being considered for replacement with coal ash is necessary, and the specific design/performance requirements for the finished project must also be understood. With this understanding, a testing program can be developed to verify that the proposed coal ash has suitable physical properties for the application.

To properly evaluate coal ash for beneficial use in civil engineering applications, it is necessary to demonstrate that the coal ash would perform comparably to the raw material being replaced. This can be accomplished through similar prequalification testing, which for beneficial use as a natural soil replacement could include testing for engineering properties such as:

Photo 1: Samples of bottom and fly ash

1. Particle size analysis (for example, ASTM D422);
2. Moisture content (for example, ASTM D2216);
3. Behavioral indexes (for example, liquid limit, plastic limit, and plasticity index via ASTM D4318);
4. Moisture-density/compaction characteristics (for example, relative density testing and/or proctor testing per ASTM D698 or D1557); and
5. Shear strength (for example, direct-shear and/or triaxial shear via various methods selected to be representative of application conditions).

Testing commensurate with that summarized previously is typically required for a natural soil fill used in common civil engineering applications. In fact, it is commonplace for such testing to be completed prior to approving a natural soil fill for use in the application (prequalification testing), and for some of these tests to be repeated at a specified frequency (conformance testing) to confirm that the fill is homogeneous, consistent, and remains suitable for the application. As such, it is reasonable that such testing would be required for a beneficial use material, such as coal ash, in civil engineering applications.

Data obtained by such testing will provide information needed by a reputable, qualified professional engineer to adequately evaluate the suitability of the coal ash for beneficial use in the civil engineering application. This may include performing detailed engineering calculations (for example, slope stability analyses) to demonstrate that replacing the natural soil fill with the proposed coal ash are relatively comparable, or what modifications to the application design (for example, reduced slope length or angle) or coal ash (for example, blending with soil or modifier such as portland cement) would be needed for suitable replacement. The data obtained may also be necessary to obtain regulatory approval for the beneficial use of coal ash in the application.

Photo 2: Example of fly ash erosion

Photo 3: Example of steep fly ash slope protected from erosion with a layer of topsoil and vegetation

TABLE 1: RANGE OF PHYSICAL PROPERTIES FOR FLY ASH SAMPLES FROM EAST COAST U.S. SOURCES

Test description and ASTM standard method	Fly ash A	Fly ash B	Fly ash C	Fly ash D
Moisture content (ASTM D2216)	0.1 to 1.7%	28.2 to 34.1%	19.3 to 24.9%	0.1 to 34.1%
Particle size analysis (ASTM D422)				
Percent finer than No. 4 sieve	100	97.6 to 100	100	96.3
Percent finer than No. 200 sieve	92.9 to 94.7	47.3 to 88	90.6	44.4
Standard proctor test (ASTM D698)				
Maximum dry density	107.0 to 114.0	51.0 to 74.1	75.0	75.0
Optimum moisture content	11.0 to 14.8	30.1 to 47.5	28.9	27.2

Once test data have been obtained, the engineering evaluation is complete, and beneficial use is substantiated, there is one further evaluation that the authors would recommend for civil engineering applications: consideration for constructibility. For instance, the fine particle size of fly ash and bottom ash can make the product highly erodible where the beneficial use application is as a soil fill replacement, and there is increased public scrutiny to any project using coal ash in this type of application. Extra planning to address the erosion potential of coal ash in this type of application is, arguably, an element of the evaluation for the beneficial use.

If coal ash is properly placed and compacted and protected with suitable erosion control measures, the material can perform adequately. In long-term exposure applications, coal ash can develop a "crust" which will shed water as long as it remains undisturbed, but even foot traffic can disturb this "crust." When initially placing coal ash, it can also severely erode as the result of one intense storm event through its entire depth of placement if runoff can travel down the gradient (Photo 2). Therefore, it is critical to protect the placed coal ash through a variety of readily available erosion-inhibiting technologies, which are also commonly employed for natural soil fill in these applications, as follows:

- Amend with a tackifying agent to provide additional resistance to erosion;
- Place and seed an overlying protective layer of topsoil (refer to the Photo 3);
- Erosion control best management practices including waddles, compost logs, silt fences, hay bales, erosion control/turf reinforcement mat; and
- Spray-application stabilization products, such as Posi-Shell®.

There is no one solution which will work in every application and the professional engineer who evaluated the application with beneficial use of coal ash would also need to be consulted with regard to constructibility issues with coal ash, whether the application be as a soil fill replacement or otherwise.

In conclusion, CCR, particularly coal ash by-products of coal-fired power plants, have potential for beneficial use in a number of civil engineering applications. Beneficially reusing CCR materials can provide the following benefits:

- Diversion of residual waste typically destined for landfill disposal;
- Cost savings by generator by not having to pay for disposal costs;
- Cost savings by end user by not using raw materials;
- End users can be more cost-competitive with their end product; and
- Reduced use of raw materials.

It is imperative that the proposed coal ash meet not only required chemical properties/constraints but also needed physical properties (that is, engineering properties) for the intended application. Further, coal ash, as with any material incorporated into civil engineering applications, should be routinely tested for conformance to evaluate homogeneity and consistency of the coal ash to maintain the requirements for a suitable replacement in beneficial use. ❖

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Robert Valorio, PE, received his BS and MS in geotechnical engineering from Drexel University. He has evaluated soils and alternate materials for use in civil and geotechnical engineering applications for nearly 20 years.

CONVERTING SULFUR FROM FLUE GAS INTO FERTILIZER

By Gail Reitenbach, PhD

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As environmental regulations tighten—both in the U.S. and around the world—coal-fired power plants continue to look for ways to operate economically. Though reuse and sale of coal combustion by-products has a long history, one new approach could benefit a somewhat unlikely partner industry.

The history of power plant emissions regulations and control technologies is largely one of preventing elements that are bad for the environment or human health—including sulfur dioxide, particulate matter, and nitrogen oxides—from being dispersed to the environment. But sometimes it's possible to take advantage of the by-products of the control technologies and put them to good use in the environment. That's the case with a new process that converts sulfur to fertilizer.

Charah Inc. has developed a technology that allows sulfur captured from power plant exhaust gases to be pelletized into a calcium sulfate fertilizer product that returns vital nutrients to farm fields. To understand why Charah and coal-fired power plants would find this worth doing, you need to understand the role of sulfur in the environment and the economics of the process.

SULFUR'S UPS AND DOWNS

When coal is burned in a boiler to generate electricity, the naturally occurring sulfur in the coal is released into boiler exhaust gases. Before it was regulated, coal sulfur was discharged into the atmosphere through plant stacks. The U.S. Environmental Protection Agency (EPA) first started regulating power plant air emissions in 1971. According to the EPA, these air quality controls covered SO2 because exposure to the gas can cause adverse respiratory effects, it can combine with other gases to produce harmful particulates, and it is a primary cause of acid rain.

Declines in SO_2 emissions began soon after enactment of the 1990 Clean Air Act Amendments, which established a national cap-and-trade program for the gas. Because coal-fired units accounted for a large share of SO_2 emissions, the program (which also covered NO_x) provided an economic incentive for coal-fired power plants to reduce emissions by installing pollution control systems, burning lower-sulfur coal, or generating less electricity.

All plants built after 1978 are required to clean the sulfur from coal combustion gases before they go up the stack. They do so with flue gas desulfurization (FGD) units, commonly called "scrubbers." The EPA reports that by the end of 2011, 60% of the U.S. coal fleet had FGD scrubbers installed.

As scrubbers began to remove sulfur from exhaust emissions, and some plants switched to low-sulfur coal, the amount of sulfur in the air decreased. EPA data shows that between 1980 and 2012 concentrations of atmospheric SO_2 in the U.S. decreased approximately 78% (Figure 1).

But sulfur need not always be a net negative for coal-fired plants. Since the 1990s, captured sulfur from flue gas has resulted

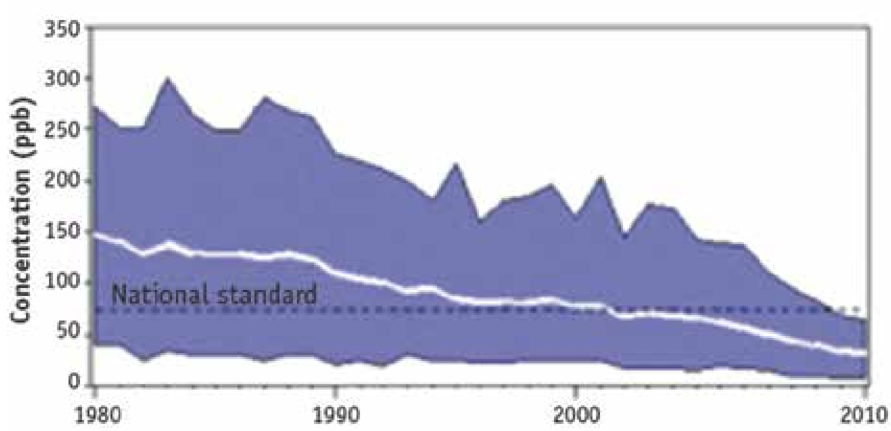

Fig. 1: Sulfur reduction. This graph shows SO_2 air quality as a national trend from 1980 to 2012 (annual 99th percentile of daily maximum 1-hour average) based on 57 sites. There was a 78% decrease in the national average over that period. Source: EPA

in the production of high-quality gypsum, hydrated calcium sulfate: $CaSO_4$-$2H_2O$. That synthetic gypsum can then be beneficially used in a number of common applications, from plaster and wallboard to cement and fertilizer. Though gypsum occurs naturally (and even lends its name to a town in Colorado with a history of gypsum mining and processing), synthetic gypsum has advantages in that it doesn't have to be mined, and it recycles what would otherwise be a waste product that power plants would have to pay to dispose of in landfills. Use of synthetic gypsum has also reduced costs for drywall manufacturers.

COAL COUNTRY CONVERSION

Charah Inc.—a Louisville, KY-based company that specializes in total ash management, including recycling by-products from coal-fired power plants—has developed a technology that allows sulfur captured from power plant exhaust gases to be pelletized into a calcium sulfate fertilizer product, providing an improvement, it says, over previous forms of fertilizer created from power plant emissions.

Charah's new facility housing this process is located at the 1,472-MW Louisville Gas and Electric Co. (LG&E) Mill Creek Generating Station, in Jefferson County, Ky. Coal provides the majority of power for Kentucky, and this plant went into commercial operation in 1972 and was LG&E's first to utilize cooling towers to protect the Ohio River's aquatic life.

Plant owners are committed to keeping this plant online. Starting in spring 2012, LG&E planned to spend approximately $1.3 billion to modernize the FGD systems and install fabric filter baghouses for increased particulate and mercury control on all units at the plant. This construction project is under way and will continue through 2015. And in November 2012, LG&E officials announced that, as part of the $1.3 billion, they would be spending approximately $940 million on clean coal technology at the station. Mike Kirkland, general manager of Mill Creek Station, told *POWER* that would include replacing existing scrubbers with new ones, installing new baghouses, and replacing exhaust stacks.

Mill Creek burns approximately 4 million tons of high-sulfur coal annually, primarily sourced from the Illinois Basin. Kenny Tapp, senior by-products coordinator for LG&E and KU Services Co., noted that over 60% of the plant's fly ash is used in the manufacturing of cement and concrete; the economic value of the fly ash utilization in concrete is estimated to be in excess of $5,000,000 to the regional manufacturers of concrete- and cement-based products. In addition, the plant realizes significant savings on landfill capacity and associated costs, though neither the plant nor Charah would release detailed data on these savings.

The plant has had wet scrubbers and a FGD slurry processing plant on its property since 1978, and its processing plant can dewater up to 1,800 tons of gypsum per day for use in the manufacturing of cement, drywall, or other uses. Now that gypsum has expanded utilization opportunities as fertilizer. This additional use can consume 200,000 plus tons per year of the total gypsum annual production.

FROM FLUE GAS TO GYPSUM

The sulfur-scrubbing process at a coal-fired power plant typically involves grinding high-calcium limestone to powder and then mixing it with water to form a lime slurry. The lime slurry is then sprayed into a contact chamber, where it combines with boiler exhaust gases and the sulfur reacts with the lime to become chemically bound.

Scrubbers come in two types: wet and dry. In wet scrubbers, the ratio of lime slurry is greater and a slurry by-product is produced. In dry scrubbers, the ratio of slurry to hot exhaust gases is controlled, to dry the lime slurry and result in a dry product. Charah has developed a process to beneficially use the wet scrubber slurry dewatered gypsum to manufacture a sulfur and calcium fertilizer.

Wet scrubbers capture sulfur from all four units at Mill Creek. The lime and sulfur slurry is aerated to create calcium sulfate, dewatered to produce high-quality gypsum, and then processed to make fertilizer at the adjacent Charah facility (Figure 2).

Mill Creek produces approximately 600,000 to 800,000 tons per year of calcium sulfate gypsum. The gypsum products are stockpiled onsite, and Charah manages the gypsum on behalf of Mill Creek.

FROM GYPSUM TO FERTILIZER

The Mill Creek gypsum typically has higher purity than natural gypsum because it has less inert impurities. Mill Creek gypsum is 90+% pure calcium sulfate. Charah utilizes this calcium sulfate gypsum to manufacture a patent-pending fertilizer named "SUL4R-PLUS product" that can be used to replenish the sulfur and calcium in farm soils, turf, and specialty crops (see sidebar). As Danny Gray, executive vice president of Charah, explained, this process essentially closes the cycle loop for the sulfur that once was returned to farm fields with rainfall, but now is removed by the power plant emissions control equipment before discharging the cleaned exhaust gases into the atmosphere.

The Charah plant accepts the gypsum when it discharges from the existing Mill Creek dewatering facility onto a new conveyor that moves it directly into the Charah plant. That gypsum serves as the feed stock for the processing steps that include pelletizing to create the granular SUL4R-PLUS product. Although synthetic gypsum has previously been used as a soil amendment, Charah says it is the first to pelletize the by-product, which makes application easier for the farmer.

That granular product is stored inside the Charah warehouse until it is transported to customers. Custom truck loading is done inside the warehouse facility. Charah also has barge-loading capability, as well as onsite railcar-loading capacity to meet customers' logistics needs. Because the Kentucky plant is located near the Ohio River, Charah can reach distant markets by barge at economical rates.

Fig. 2: Conversion site. The Charah product manufacturing facility sits on the Louisville Gas and Electric Co.'s Mill Creek Generating Station property in southwest Jefferson County, KY Courtesy: Charah Inc.

The sulfur level of SUL4R-PLUS product is greater than 16%, its calcium level is greater than 20%, and the product looks like and handles like any other granular fertilizer (Figure 3). Farmers can replenish the sulfur depleted by crops from farm soils by applying SUL4R-PLUS product along with their other fertilizers. The product has a unit weight of approximately 50 pounds per cubic foot and spreads in common distribution equipment in a single pass across the field.

WIN-WIN ECONOMICS

In nations where power plant emissions are tightly regulated, adding beneficial reuse of by-products is likely to become an increasingly valued option for the future business case. At full capacity, more than 50% of Mill Creek's gypsum will be beneficially used. By avoiding disposal of the recycled by-products, LG&E realizes lower operating costs, which help lower electricity costs for the utility's customers.

Additionally, Gray says Charah's granular fertilizer provides good economic value to the American farmer, as typical prices of SUL4R-PLUS product are 20% to 30% lower than alternative sources of sulfur equivalents.

Charah's investment of $12 million to $14 million in 2013 has provided a first-of-its-kind manufacturing plant to convert high-grade calcium sulfate into a new agriculture product. The plant is designed to reclaim up to 300,000 tons per year of gypsum and

Fig. 3: From power plant to pelletized fertilizer. Courtesy: Charah Inc.

Sulfur's Role in Agriculture—A key component of agriculture production in the U.S. has been the proper deployment of various types of fertilizers. Historically, the primary fertilizers have been nitrogen (N), phosphorus (P), and potassium (K). High-efficiency farming requires that particular attention be focused on secondary nutrients, which include calcium (Ca), magnesium (Mg), and sulfur (S). Sulfur has become more important to high production and is often referred to as the "fourth major nutrient." Each of the secondary nutrients is essential for high-intensity farming activities. Though required in smaller quantities than NPK, they are essential for plant growth. As a nutrient, sulfur is needed in significant quantities by many crops that utilize approximately the same amount of sulfur as they do phosphorus. A typical crop, such as corn or soybeans, can extract and remove from the soil 12 to 20 pounds of sulfur per acre (Table 1). The sulfate ion (SO_4) is the form of sulfur absorbed by most plants. Replenishment of sulfur is crucial to maintain high production on each acre. Typical sources of sulfur include organic matter, ammonium sulfate, gypsum, zinc sulfate, and elemental sulfur.

Table 1. Typical nutrient uptake. Source: Charah Inc.

Typical nutrient uptake				
Crop	Yield	Nitrogen (lb/ac)	Phosphate (lb/ac)	Sulfur (lb/ac)
Corn	200 bu/ac	150	85	15
Soybeans	60 bu/ac	240	48	12
Wheat	80 bu/ac	92	44	7
Alfalfa	6 ton/ac	225	60	30

Notes: ac = acre, bu = bushels.

produce up to 250,000 tons of SUL4R-PLUS product fertilizer. It also created up to 25 new jobs in the recycling industry.

At power plants that generate a high-quality gypsum product, Charah says a manufacturing plant can be custom designed and installed within 12 months. Charah provides the capital for SUL4R-PLUS plants and maintains owner and operator status. Agreements between Charah and the host power plant typically extend over five to 15 years. Charah plans to develop and install SUL4R-PLUS manufacturing plants throughout the U.S. at strategic locations to meet the growing demand for agricultural sulfur products. ❖

— Gail Reitenbach, PhD, *is* POWER*'s editor (@GailReit, @POWERmagazine).*

COLD IN-PLACE ASPHALT RECYCLING WITH CLASS C FLY ASH

By Dr. Tyson Rupnow and Ben Franklin

In 2006, the parking lot at Iowa State University's (ISU's) Jack Trice Stadium was deteriorating quickly, as evidenced in Fig. 1 and 2. Base failures were occurring across the parking lot at an increasing rate. A repair plan was needed but, as usual, budgets were tight and the owner was looking for a solution that fit ISU's tight financial constraints. The existing parking area was constructed with 6 in. of hot-mix asphalt over a compacted subgrade. Because it did not have a more robust subgrade, this pavement was not designed to provide an extended service life. However, because the parking lot did not have continual heavy use, the owner was comfortable with the original design.

Jack Trice Stadium, Iowa State University, Ames, IA

Fig. 1 (top) and 2 (bottom): Deteriorating asphalt pavements

When the discussion of repair options began, the focus quickly came to placement of new hot-mix asphalt over a more robust support system. The final designs considered included 8 in. of gravel stabilized with an asphalt emulsion or 12 in. of reclaimed asphalt pavement, also known as RAP, stabilized with Class C fly ash. Both proposed stabilized bases would be placed over compacted soil. After careful consideration of the properties of both designs, the cross section with the fly-ash-stabilized material was selected.

The fly ash used for this project came from three sources. The Ames Municipal, Ottumwa, and Prairie Creek power plants all provided material. The ash was added to the RAP at the rate of 10%.

The construction plan was typical of this type of project. First the existing pavement was reclaimed and windrowed. The subgrade was graded to plan, conditioned for optimum moisture content, and compacted. Next, the Class C ash was spread along with the reclaimed asphalt. The ash and the asphalt were thoroughly mixed. Compaction followed the mixing process. The final step in subgrade preparation was to water the ash-asphalt mixture to activate the calcium oxide in the Class C ash to stabilize the subgrade. The subgrade was now ready to receive the new hot-mix asphalt pavement.

Quality control/quality assurance testing in both the laboratory and the field provided the necessary data to qualify

the materials and the process used. The laboratory work included analysis of the fly ash, determination of optimal gradations, fly ash and moisture content, Proctor determinations, and determination of unconfined compressive strength. Field testing included dynamic cone penetrometer measurements and unconfined compressive strength testing.

As mentioned earlier, one of the primary controlling factors for this project was cost. At \$4.10/yd^2, the fly-ash-stabilized design was less than half of the cost of the emulsion-stabilized design at \$9.40/yd^2. Because both designs were to receive the same hot-mix application, the hot-mix asphalt is not included in these costs. The only question remaining was: Did the repair perform to the owner's expectations?

We visited the project during the winter of 2014 and found the answer to the question was a resounding "yes." Figures 3 through 5 provide some evidence that the pavement is performing as anticipated. Some 8 years after the repair project was finished, the owner has only performed routine maintenance tasks, such as an occasional sealcoating and annual striping. ❖

Fig. 3 (top), 4 (middle), and 5 (bottom): 8 years after reconstruction, the pavement is performing as expected

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FLOWABLE FILL POTENTIALLY CUTS MONTHS OF CONSTRUCTION

By Hank Keiper, P.E., The SEFA Group

Anyone who has driven a motor vehicle in Baltimore or Washington, DC, in the past 30 years knows one word that inspires anxiety, fear, and trepidation: beltway. In the case of Baltimore, MD, the beltway is I-695 and it completely encircles the city, crossing the Patapsco River over the Francis Scott Key Bridge in the southeast corner near Dundalk. Like every Patapsco River crossing, motorists pay tolls for crossing the Key Bridge. Tolls are currently collected at a single 12-lane toll plaza on the northeast end of the bridge.

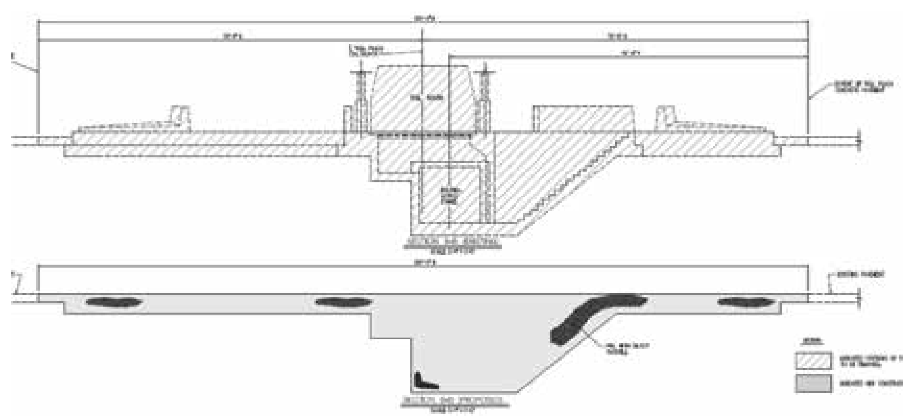
As the use of electronic toll transponders has grown, the bridge's owner, Maryland Transportation Authority (MdTA), proposed eliminating the tollbooths and collect tolls entirely electronically. Motorists without transponders would receive an invoice in the mail based on license plate photographs. Vehicles would whiz through the open plaza at highway speeds, reducing congestion and the awkward merging associated with traditional tolling facilities.

Each tollbooth at the Key Bridge is currently accessed by a set of stairs and an 8 x 8 x 258 ft tunnel running under the toll plaza. In addition to demolishing the booths and concrete barriers, the entire tunnel and each stairwell would be removed by cut and cover, essentially creating a 14 ft deep x 50 ft

wide ditch across one of America's busiest interstates for at least 3 months. The project was designed in three phases to stagger the construction and help with maintenance of traffic.

Fortunately, the design consultant hired by MdTA reached out to the ready mix concrete industry in Maryland for information on abandoning the tunnel using controlled low-strength material or flowable fill. This project is an excellent candidate for using flowable fill with fly ash as a primary constituent. Each of the 10 stairwells offers an opening to dump the material directly into the tunnel. In addition, each stairwell provides a flowable fill reservoir higher than the tunnel ceiling to maintain positive head during subsidence. The project will take approximately 800 yd^3 of flowable fill, which can be easily accomplished in 1 day by the concrete producers within a few miles of the plaza. The flowable fill could be split into two placements to reduce subsidence if desired by the owner. Maryland is also home to several beneficiated and by-product fly ash sources!

The benefits of using flowable fill on this project are enormous. The first, of course, is safety both for the workers and the traveling public. Instead of a deep trench literally adjacent to the Baltimore harbor, virtually all of the work can occur at grade level. Instead of months of lane shifting, flagmen, signboards, dewatering, jackhammering, and orange barrels, most of the tunnel activity will occur in 2 days. Another benefit to the owner is the quality of the product. Because the existing tunnel will remain structurally sound and filled, there will be very little chance of future soil subsidence with associated repair work. On the other hand, a cut-and-cover contractor will be under significant pressure to rapidly compact the select fill material and close up the cut. Even with strict density and compaction monitoring of the embanked material, the opportunity for less-than-optimum compaction exists. The final benefit is a dramatic reduction in time to complete the project. As much as 3 months could be cut from the



schedule. That's 3 months of greater rush-hour congestion; 3 months of dump trucks hauling away debris delivering borrow material, and 3 months of Chesapeake Bay weather to further delay the work.

Unfortunately, this is a good-news/bad-news story. The good news is MdTA agreed that abandoning the tunnel with flowable fill was an excellent design and construction solution. The bad news is public opposition to all-electronic tolling at another MdTA facility has stalled the all-electronic tolling project for several years. When the time comes, the Maryland concrete industry will be ready with a flowable fill solution. ❖

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ENVIRONMENTAL WIN-WIN

ARIPPA's Role: Cleaning Up Historic Coal Waste Sites, Restoring the Land Using Ash

One of the largest-volume coal ash beneficial use success stories in the United States is told in one of the nation's oldest coal fields.

The anthracite region—located in and around Pennsylvania—is home to a coal industry dating to the mid-1800s or earlier. Many decades of coal production for energy and steel manufacturing produced literal mountains of coal refuse—the rocks and dirt that was separated from the coal after mining. In an era long before environmental regulations, billions of tons of coal refuse accumulated over more than 189,000 acres in Pennsylvania alone. More than 5000 mine sites were abandoned.

These coal refuse piles are not just unsightly. They create acidic water that degrades more than 5500 miles of streams and associated groundwater throughout the region. Abandoned mine workings also pose physical hazards for people living in the area.

But what if there was a way to productively use that coal refuse and then restore the land around it? For the past 25 years, ARIPPA has been showing that there is.

LEADING THE WAY IN MINING LANDS RECLAMATION

Now known simply as ARIPPA, the Pennsylvania-based trade association started life as the Anthracite Region Independent Power Producers Association. ARIPPA members operate power plants that use modern circulating fluidized bed (CFB) technology to generate electricity using the abundant, but low energy value, coal refuse as fuel. The ash remaining after electricity is generated and is then used to reclaim abandoned mine lands in an environmentally responsible manner.

Since 1988, ARIPPA members have removed more than 212 million tons of coal refuse and used it to generate electricity. They have subsequently reclaimed and restored more than 8200 acres of damaged mine lands and hundreds of miles of formerly dead streams.

ARIPPA's Executive Director Jeff A. McNelly said that the unique nature of modern CFB technology combined with the industry's desire to work in conjunction with various environmentally concerned hands-on volunteer groups and governmental agencies clearly indicate the industry's commitment to being an environmentally beneficial alternative energy industry.

"Our industry's private, non-tax-dollar efforts combined with the volunteer- and tax-payer-supported state/federal government programs combine to form a dedicated and concentrated plan to rid our lands of the significant environmental hazards that abandoned mine lands have created," McNelly said. "Such hazards endanger the public, and limit economic development and recreational opportunities in mining communities."

RECLAMATION AS AN INDUSTRY

The CFB power plants operated by ARIPPA members annually generate between 3 and 5% of the total electric generation in the Pennsylvania and West Virginia region, supplying hundreds of thousands of homes and industry with much-needed alternative energy while at the same time directly and indirectly employing thousands of workers.

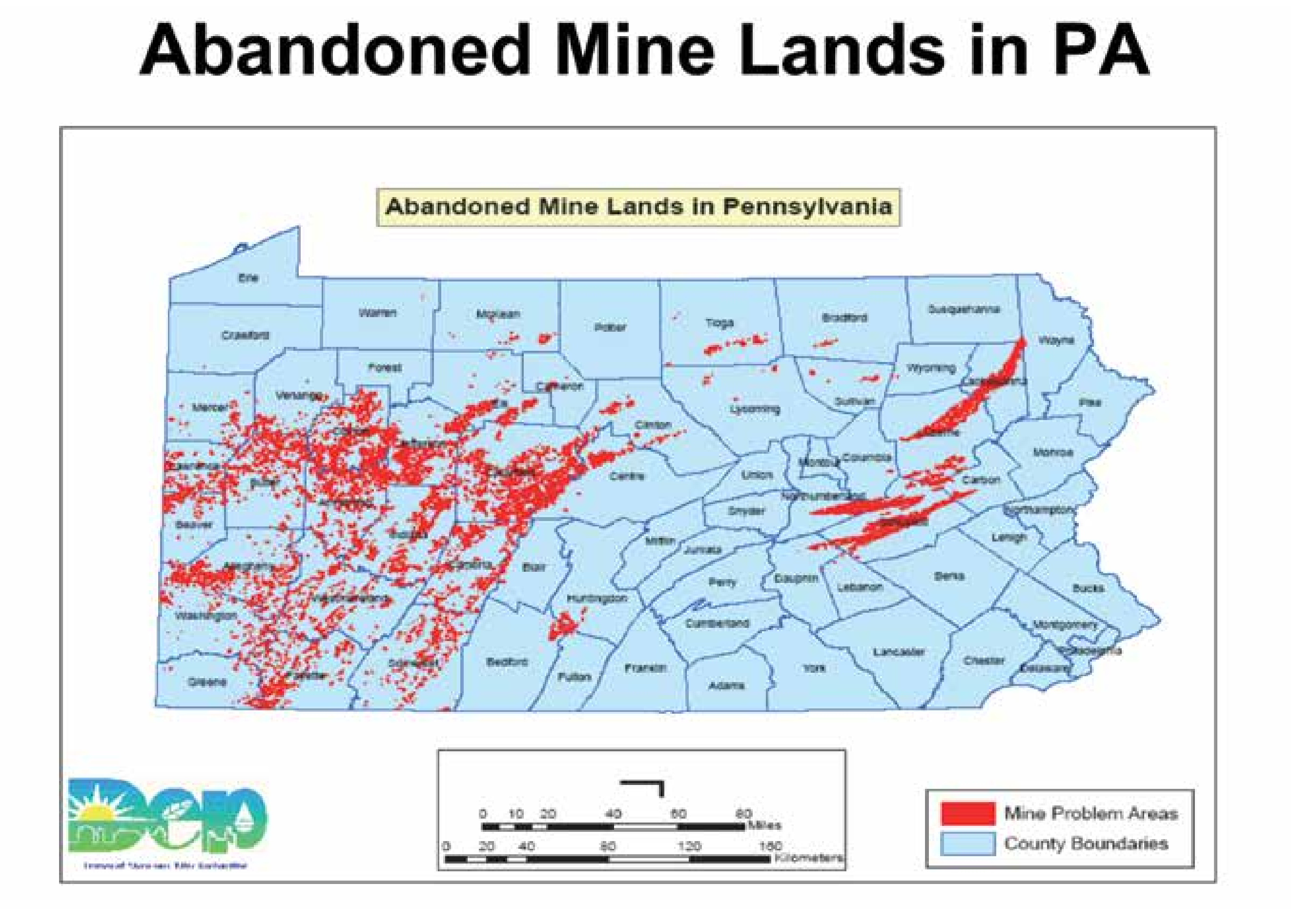
In celebrating its 25th anniversary this year, ARIPPA published impressive industry statistics. Since 1989, ARIPPA members have collectively:

- Removed and converted more than 212 million tons of coal refuse into alternative energy.
- Reclaimed over 8200 acres of formerly environmentally damaged mine-scarred lands.
- Restored approximately 1200 miles of formerly dead polluted streams.

A historic "breaker"—a plant used to separate high-quality coal from rocks and waste materials that accumulated in huge coal refuse piles

"Breaker boys" performing the back-breaking work separating coal from refuse in the 1800s

A typical coal refuse pile, similar to hundreds dotting the landscape in the anthracite region



Abandoned mine lands affect wide stretches of the Commonwealth of Pennsylvania

Surface water contaminated by acid mine drainage is a major environmental problem that can be corrected through mine reclamation

Coal ash is used in well-engineered fills to reclaim damaged mine lands and return them to safe and productive use

Reclaimed mine lands can be used for a variety of public and commercial purposes

- Eliminated public safety hazards, including hundreds of uncontrollably burning coal refuse fires emitting naturally occurring ground level pollutants.
- Produced 1500 megawatt-hours annually of alternative energy and steam.
- Donated thousands of dollars to various deserving volunteer watershed and conservancy groups performing abandoned mine land (AML) and/or acid mine drainage (AMD) remediation improvements.

RECLAMATION ACTIVITIES HIGHLY REGULATED

In 2010, Pennsylvania's Department of Environmental Protection reported that "Pennsylvania has the nation's largest abandoned mine problem, with approximately 180,000 acres of cliffs, coal refuse piles, and other dangerous features encompassing abandoned mine lands, some dating back to the 1700s. More than 2 billion tons of coal refuse sits in piles across the state, resulting in acid mine drainage which is the largest source of water pollution in the state, degrading 5500 miles of rivers and streams."

Pennsylvania's Bureau of Abandoned Mine Reclamation estimates the cost to eliminate these abandoned mine problems and complete the cleanup of AML-AMD sites in Pennsylvania to be approximately $14.6 billion of taxpayer funds and take nearly 500 years.

Faced with such a daunting challenge, Pennsylvania environmental regulators have embraced the opportunity to work with the private sector to address coal refuse problems. The resulting public-private initiative takes advantage of the characteristics of coal ash while providing strict regulatory accountability.

Ash from CFB power plants is unique. Power plants that burn coal refuse produce a higher percentage of ash than other types of power plants because much of the fuel is rock that does not burn. Additionally, these plants add limestone to the boiler to prevent air pollution. The limestone adds to the volume of ash, but it also imparts alkalinity. Ash is often returned to the area from which the coal refuse was extracted, thus substituting an alkaline material for an acidic material and enabling improvement of water quality.

In the mid-1980s, the Pennsylvania Department of Environmental Protection began to approve coal ash use for mine reclamation. When an applicant proposes to use a source of coal ash for beneficial use in Pennsylvania, extensive chemical testing is required of the ash to determine concentrations of elements that might cause environmental problems. The Department has guidelines for permissible concentration levels. Twenty-one different parameters are used to assess the dry ash composition and the leachate characteristics. If an ash exceeds the limits, it cannot be used beneficially and must be disposed in a lined facility.

The Department also reviews the geology and hydrology of the mine site to assure that the ash can be placed in an environmentally safe manner. If the Department determines that placement of ash at a mine would create a problem (either because of the site or the ash quality), the proposal is rejected.

A QUARTER-CENTURY AND JUST BEGINNING

In celebrating its silver anniversary this year, ARIPPA released a 40-minute documentary on the "Legacy of Coal." (It is available for viewing on the organization's website at **www.arippa.org**.) Tracing the historic origins of the anthracite region's massive coal refuse piles and the relatively recent actions to use them productively, one thing becomes clear: It will take many more decades of efforts like ARIPPA's to overcome centuries of environmental damage.

PURR-FECT HARMONY® ADVANCED CLUMPING CAT LITTER

The PURR-fect Solution for a better planet.™

Recycle More! Turning Fly Ash into Cat Litter…

Anybody involved with fly ash knows that the recycling of this valuable material is one of, if not the greatest, American recycling success stories. In 2012, approximately 23 million tons of fly ash were beneficially used in various recycling applications—thus preventing this material from being landfilled. Unfortunately, this only represents approximately 45% of the fly ash produced each year in the United States, so the need for new and innovative uses of fly ash are still required. Our company, PURR-fect Solutions, LLC™, and its research team have been performing research and development (R&D) on fly ash materials for many years for various scientific applications. All along, we were guided by one simple motivation: recycle more—take advantage of the wonderfully useful chemistry of these materials. And somewhere during this fantastic voyage in R&D, we stumbled upon a novel and unique way to make an environmentally friendly cat litter!

As luck would have it, during the time we were investigating fly ash recycling options, several team members voiced their deep displeasure with the current products on the market for green cat litter alternatives (versus traditional bentonite clay). Green litter products have skyrocketed annualized growth rates (approximately 20% per year). Consequently, a flood of new green litters are currently on the market; unfortunately, none of these products perform anywhere near as well as traditional clay products—the "gold" standard for this industry. For instance, the clump integrity is poor, the odor control is subpar, and the materials used for manufacture are often rejected by cats. Let's face it: cats are not used to "doing their business" on wheat or corn substrates—they prefer dirt or sand! It seems that nothing performs as well as the "gold standard"—that is, traditional sodium bentonite clay, which was introduced to the market in the early 1980s. Hence, product performance is why green litters, despite their solid growth, are still being dominated by traditional clay litters. Clay litters are responsible for approximately 75% of the $2 billion per year market for pet litter in the

TABLE 1: COMPARISON OF CHEMICAL MAKEUP OF FLY ASH LITTER VERSUS BENTONITE CLAY LITTER

Chemical analysis	PURR-fect HARMONY® (fly-ash-based material)	Bentonite clay litter
Silicon dioxide, %	39.1	58.6
Aluminum oxide, %	18.6	24.8
Iron oxide, %	6.0	3.0
Calcium oxide, %	22.6	3.0
Magnesium oxide, %	5.5	2.0
Sodium oxide, %	4.0	0.2
Potassium oxide, %	1.0	0.3
Sulfur trioxide, %	2.0	0.1
Titanium dioxide, %	0.3	0.3
Other, %	0.9	7.7

United States, which continues to grow at approximately 3 to 4% per year (even despite the latest recession).

So what is the problem with using bentonite clay? The problem is strip mining virgin materials so they can be used to hold animal waste. The practice of strip mining for pet litter is very environmentally damaging. For every ton of clay removed from the earth, 4 tons of overburden are removed to unearth the clay. Some of this country's most beautiful landscape is bulldozed to mine bentonite clay for pet litter! Why don't we preserve this resource for more valuable applications? Pet owners are faced with a choice: use an inferior—but green—litter product or unnecessarily damage the earth for the convenience of a high-performing clay cat litter.

THIS IS NO ORDINARY LITTER

Our research work using fly ash allowed us to see an opportunity, which was to use fly ash to create a new type of litter that not only looks and feels like clay, but one that also actually performs like clay. The resulting product is PURR-fect HARMONY® advanced clumping cat litter—the only green cat litter that looks like clay, feels like clay, and that your cat thinks is clay. Currently, we offer our product in two sizes (shown in the picture), a 12 lb trial size, and the more economical bulk bag containing 22 lb. PURR-fect HARMONY is the only advanced clumping cat litter that combines the high standard of performance expected of clay with the environmental benefits of "natural" litters. PURR-fect HARMONY contains 85% fly ash that is beneficially recycled into the product. Our substrate is virtually indistinguishable from clay. Why? As Table 1 shows, the chemical makeup of sodium bentonite clay is very similar to the chemical makeup of fly ash. Consequently, the main difference between our litter materials and clay litter is not the chemistry but rather the overall material structure. So it is no coincidence that we look and feel like clay because chemically, we are clay!

The manufacturing process is environmentally friendly because it avoids the need for strip mining to obtain the bentonite clay and reduces the amount of fly ash that has to be landfilled by power plants. Using a scientifically formulated and patented process, we transform and encapsulate the fine fly ash materials into an absorbent cat litter with a range of particle sizes. Our fly ash comes from the Coronado Generating Station in St. Johns, AZ, marketed by CEMEX/MRT. Although our proprietary process is applicable to both Class C and Class F ashes, our process has been optimized for Class C ash. Our current pilot-scale production facility is located in Salt Lake City, UT, and it has the capacity to produce well over a million pounds of litter annually.

The remaining 15% of the product uses all-natural materials to achieve its quadruple odor protection and superior clumping strength. In designing our product, we elected to not use any fragrances to cover or mask the odor; rather, we chose to attack the odor at the source. Our odor-blocking agents were carefully selected by our team of scientists to protect you from malodor in four distinct ways: absorb, capture, neutralize, and prevent litter box odor. This powerful combination is also good for single- or multi-cat households. Our best-in-class clump strength is the result of a unique natural polymer made from a seaweed extract. When it makes contact with liquids, the polymer naturally swells and forms a strong bond between neighboring particles within the litter. Unlike most natural litters, which have poor clump integrity, our litter clumps remain intact even after being dropped from a 1 ft height. This is no ordinary litter!

THE FUTURE OF PURR-FECT HARMONY

The growth potential for our product is enormous, and the number of stores carrying our product continues to grow each month. Many pet specialty retailers crave innovative new products that help differentiate them from "big box" stores and grocery chains. The uniqueness of our product and its positioning in the marketplace benefits not only us but also the retailers who carry us. We hope every cat parent will realize that by switching to PURR-fect HARMONY cat litter, they can do something positive for the world without having to sacrifice anything.

PURR-fect Solutions, LLC™ is excited to provide another avenue for the beneficial reuse of fly ash—one that is recession-proof and quite unique. Our vision is to continue to pursue innovative uses of fly ash to expand its recycling potential rather than landfill this valuable chemistry.

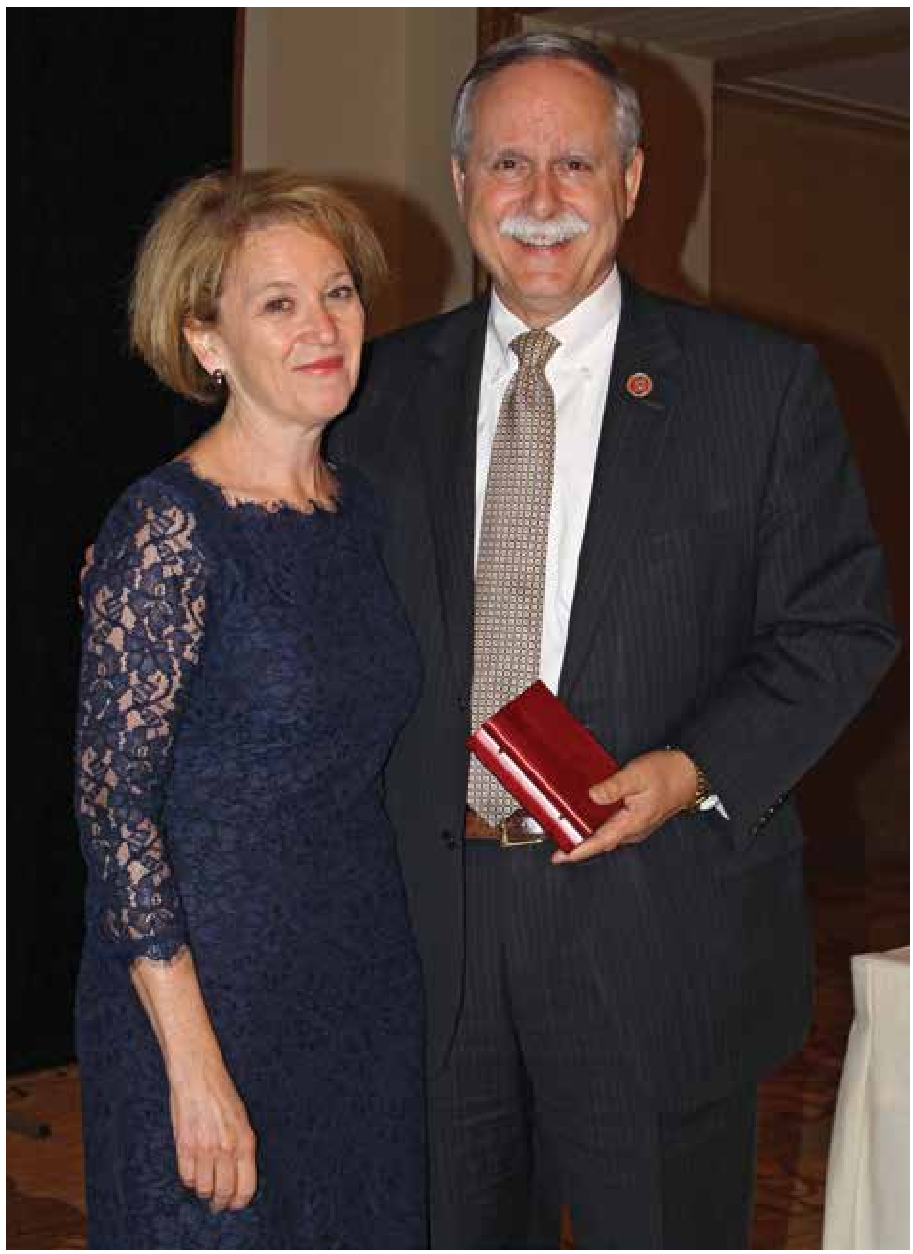
For more information, please visit our website at **www.purr-fectharmony.com**. You can also visit our Facebook page (**www.facebook.com/harmonylitter**) to learn more, including locations where PURR-fect HARMONY is available. ❖

CONGRESSMAN DAVID MCKINLEY— A NEW ACAA CHAMPION

In 2012, the American Coal Ash Association established a new award to recognize extraordinary contributions to the beneficial use of coal combustion products: the ACAA Champion Award. The recipient is selected exclusively by the Chair of the ACAA Board of Directors and is known only to the Chair until the moment the presentation is made. The recipient may be an individual or individuals; an institution—private or public; a member of the ACAA or a non-member; living or deceased.

What constitutes extraordinary contributions to the beneficial use of CCP? In this case, beauty is truly in the eye of the beholder. Over the decades of beneficial use, many, many important contributions have come from a wide range of sources. Advances in research, innovative use of CCP, extraordinary marketing efforts, educational leadership, leadership for the industry through participation in technical organizations, involvement in regulatory activities, and protecting beneficial use from assaults by outside interests are examples of worthy contributions. The biggest challenge for the initial awards is to sort through the myriad of worthy recipients and select just one.

In 2012, Mark Bryant concluded his 4 years as Chair of the ACAA Board of Directors by presenting the very first ACAA Champion Award to John Ward for his exceptional work in providing leadership in meeting challenges from the U.S. Environmental Protection Agency and ENGOs following the Kingston, TN, ash spill in December 2008. Bryant noted that



Chair of the ACAA Board of Directors Lisa Cooper presents Congressman David B. McKinley with the ACAA 2014 Champion Award.

the immediacy and intensity of the assault on beneficial use by those opposed to coal-fired generation of electricity challenged the very survival of the beneficial-use industry. With his deep experience in the machinations of Washington, DC, John Ward was able to provide top-notch advice and guidance to the association.

One year later in Pinehurst, NC, Chair Lisa Cooper bestowed the second award to retired ACAA Executive Director Dave Goss. While Goss has continued to manage special projects for the ACAA since his "retirement," he really did want to retire. Chair Cooper thought it was time to recognize Goss for his service to the ACAA over more than a decade. During his tenure as COO of the association, ACAA came back from a very fragile financial condition, carefully grew the services provided, increased membership, and improved the reputation of the ACAA to outside organizations. Goss also brought the ACAA together with the Center for Applied Energy Research at the University of Kentucky to create the highly successful World of Coal Ash. Working with leaders from the ACAA membership, Goss nursed the ACAA back to health.

The next ACAA Champion Award was presented this past June in Pittsburgh, PA. As one of her last actions as Chair of the ACAA Board, Lisa Cooper named Congressman David B. McKinley as the third recipient. Congressman McKinley, from the first Congressional district of West Virginia and a registered professional engineer with a deep knowledge of beneficial use of CCP, became the elected voice for beneficial use in the U.S. Congress in his very first month following his election in 2010. Within 30 days of being sworn into office, McKinley authored a bill preventing the EPA from creating hazardous waste regulations for the management of CCP. That one-paragraph bill was the first in a series of bills passed by the House of Representatives with bipartisan support. During the process of getting his bill through the House Energy and Commerce Committee, Congressman McKinley has had to twist many arms to get attention on the issue, even confronting Speaker of the House John Boehner in a heated discussion. Today, five bills directing the EPA to create a CCP management plan closely following that used for municipal solid waste have passed the House. The last bill, HR 2218, passed in April 2013, was praised by President Obama following passage. Yet Senator Harry Reid and the Democrat majority in the Senate will not take action on the bill. All efforts to get the bill through the Senate have been end-runs because Senators Harry Reid and Barbara Boxer will not allow this bill to go through in regular order. McKinley is clearly not a career politician. At an age when most successful businessmen are off golfing, sailing, traveling, and enjoying the fruits of a career, McKinley chose to go to Washington to try and fix things. In the dark days of 2010, the ACAA needed a strong, passionate champion in Washington, DC. David B. McKinley was the right man at the right time.

The ACAA maintains a plaque with the names of the recipients of the ACAA Champion Award. It is on display at every ACAA meeting. Who will be the fourth recipient? Only one person knows and he is not talking. We will find out at the ACAA 2015 fall meeting.❖

A STUDY IN COLLABORATIVE SUCCESS: A PROPOSAL TO SUSTAIN IT

Anne Weir, Executive Director, Association of Canadian Industries Recycling Coal Ash (CIRCA)

"The Agency believes that these beneficial uses provide significant opportunities to advance Sustainable Materials Management"[1] ... It was with a sense of relief that the coal ash industry read these words in the U.S. Environmental Protection Agency's (EPA's) February 2014 report, where it supported beneficial use of coal fly ash in concrete and flue gas desulfurization (FGD) material in wallboard and reconfirmed the environmental safety of encapsulated applications. Yet this restoration of legal certainty[2] for coal combustion product (CCP) use is notably subdued, considering it requalifies nearly 6 years of uncertainty for an industry with such a capacity to contribute to the economy and the pursuit of sustainability.

So much has happened since the Kingston, TN, spill that prompted the EPA to pull its plug on multi-agency government support[3] for beneficial use of coal ash that it can be tempting to look past the hard-won knowledge that shaped the industry's pre-Kingston reality in favor of something more current, assuming "current" is more relevant; yet this would be an unfortunate over-simplification. This article unearths enduring facts about beneficial use of CCPs—facts nearly obscured by a multitude of more recent, but potentially misleading, inputs. As "those who cannot remember the past are condemned to repeat it,"[4] this article is intended to clarify the merits and underscore the value of CCPs' beneficial use in a range of applications,[5] including expanded recovery of needed minerals.[6]

Post-Bevill (2000)[7] and pre-Kingston (2008), an irrefutable case was made for fly ash concrete in industry literature which effectively stated a science-based, quantifiable case for beneficial use. After years of tussling over details of approaches to life-cycle analyses and emissions protocols, clear means were established by which to evaluate and monetize the efficacy of material replacements in the interest of sustainability

1 "Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard," U.S. Environmental Protection Agency, Washington, DC, Feb. 2014, 91pp., http://www.epa.gov/epawaste/conserve/imr/ccps/pdfs/ccr_bu_eval.pdf.

2 "The development of sound legislation, regulations and other necessary measures designed to provide industry with the level of 'legal certainty' are a minimum requirement for capital investment in modern economies. These investments provide for efficient and effective recovery or value-adding 'best use' of CCPs for beneficial ends. … 'legal certainty' …underpins all corporate commercial decision-making processes. Ambiguity associated with the materials classification will only result in hesitancy for further investment into future utilization technologies…In the absence of legal certainty, generators, investors, business owners and customers operating in highly-competitive commercial markets typically avoid regulatory uncertainty or risks associated with an activity, resulting in the widespread loss of current and future beneficial utilization opportunities for CCPs." Heidrich, C.; Feuerborn, H.-J.; and Weir, A., "Coal Combustion Products—A Global Perspective," *VGB PowerTech*, V. 93, No.12, Dec. 2013, pp. 46-52, http://www.vgb.org/vgborg/en/pt_12_2013.html.

3 From 2003 to July 2009, the Coal Combustion Products Partnership (C2P2) allied U.S. Departments of Environment, Energy, Highways and Agriculture, and other proponents of beneficial use (ACAA, USWAG, CIRCA, and industry stakeholders) championed increasing beneficial use of coal combustion products in the United States. http://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/6825758/FID3536/pdfs/c2p2facts.pdf.

4 Santayana, G., *The Life of Reason, Vol. 1: Reason in Common Sense*, 1905, http://www.gutenberg.org/files/15000/15000-h/15000-h.htm.

5 ACAA statistics itemize 15 beneficial use categories; Canadian publications list six, with "Other" representing "waste stabilization, specialty uses such as mineral filler and flowable fill." Prior to 2000, Canadian statistics detailed 12 use categories, with "Other" uses including "oil well reclamation/cementing agent, microspheres and roofing tiles." ACAA "2012 Coal Combustion Product (CCP) Production & Use Survey Report": http://www.acaa-usa.org/Portals/9/Files/PDFs/revisedFINAL2012CCPSurveyReport.pdf; Natural Resources Canada "Production and Use Of Coal Combustion Products (CCPs), 2010-2012 Average": http://www.circainfo.ca/documents/2010_2012CCPSurvey-NRCan.pdf; Natural Resources Canada "Total Coal Combustion Products (CCPs) Production and Use—1999: http://circainfo.ca/members/documents/PandUstats1999.pdf

6 "Utilization of Coal Ash from Landfill," Association of Canadian Industries Recycling Coal Ash (CIRCA), Apr. 2013, 2 pp., http://www.circainfo.ca/documents/Circa_FactSheet10_FINALUtilizationfromLandfill-03.pdf.

7 "Notice of Regulatory Determination on Wastes from the Combustion of Fossil Fuels," delivered May 22, 2000, ruled national regulation of coal ash is appropriate under nonhazardous (Subtitle D) authorities in landfills and surface impoundments, http://www.epa.gov/epawaste/nonhaz/industrial/special/fossil/ff2f-fr.pdf.

and related economic impacts.[8] Industry leaders in Canada[9] and the United States put their findings to constructive use, encouraging innovation through design and construction specifications and practices accomplished through increased use of supplementary cementitious materials (SCMs), of which fly ash represents the greatest proportion.[10] Improved technical performance alongside significantly reduced environmental impacts proved persuasive:

- "…prescriptive codes lead to considerable waste of cement, while adversely affecting concrete's durability. [They] must be replaced with performance-based specifications that promote durability and sustainability."[11]
- "Use of reclaimed and recyclable industrial by-products…to partially replace Portland cement in concrete, reduces GHG emissions and results in sustainable "green" concrete…benefits include minimization of waste disposal…lessened pressure on natural resources…concrete using SCMs will generally exhibit an extended service life over conventional concrete."[12]

Industry stakeholders took up the cause, making efforts on every front (education, advocacy, standards development, communications, and promotion) to increase beneficial use of SCMs/CCPs, despite implications for the status quo. "About the same time, environmental regulation increased pressure on industry to reduce emissions and the coal-fired power generation and cement industries came under increasing scrutiny. Also, at about the same time, the International Energy Agency identified "clinker substitution" as a key strategy to reduce CO_2 emissions from cement manufacture. These forces galvanized complementary objectives into something of a silver lining, encouraging Coal Ash Producers and Marketers into profitable and productive partnerships that support both industries' aspirations to increase sustainability."[13]

Post-Kingston, detractors of every stripe capitalized on ignorance of coal ash chemistry, its management, and attendant public concern to gain political advantage. Dave Goss, ACAA Executive Director at the time, characterized the political landscape with which the coal ash industry was coping:

> "Competitors of CCPs raise [the spectre of comparative toxicities]…this stigmatization has a genuine adverse impact on…[current and future] use.…It is a travesty that this highly successful example of industrial recycling may be lost due to issues that are largely political in nature and not at all related to the material itself…the use/re-use of CCPs supports sustainable practice and should…be increased."[14]

While many stakeholders stuck by science[15] and sustainability[16] to advance CCP use, provide input to the EPA, and appeal to common sense, others filled the vacuum left by withdrawal of government support with everything from resounding silence to damning ambiguity.[17] This was perhaps predictable, as the battle to influence public perception of CCPs is an enduring skirmish in the fiercely competitive construction materials market. Economist Jeffrey Sachs suggests that "economy is intimately interconnected with a much broader drama that includes politics, social psychology, and the natural environment…,"[18] that understanding of issues is best appreciated as

> "a big canvas, in which culture, domestic politics, geopolitics, public opinion, and environmental and natural resource constraints all play important roles..."[19]

Although the EPA has re-established that prudent coal ash use will support "public good" through "sustainable materials management" and although there is agreement this will yield higher-performing, more sustainable infrastructure when it is most needed, challenges remain. Today's specifiers, and policy- and decision-makers navigate conflicting inputs born of competing agendas, the flotsam of two "perfect" storms (Bevill Amendment and Kingston spill). In other words, as some barriers to CCP use are removed, others have developed to replace them. Meanwhile, significant change since 2000 and 2008 makes for a very different canvas: climate change is acknowledged as fact and anthropogenic influences upon it are confirmed[20]; proposed 30% cuts to U.S. coal-fired power production will reduce coal ash supplies as a matter of course. Under these circumstances, recent Canadian experience—including Ontario-legislated closure of coal-powered plants in

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8 "Beneficial use of fly ash in concrete and FGD gypsum in wallboard results in positive environmental impacts…most significantly energy savings ($4.7 billion in 2007 energy prices, enough energy to power over 4 million homes for an entire year), water use reductions ($76.9 million in 2007 water prices, roughly equivalent to the annual water consumption of 61,000 Americans)…, avoided greenhouse gas (11.5 million tons of avoided CO_2 equivalent and [other] air emissions (30.3 million kilograms of avoided NO_x, and 23.9 million kilograms of SO_x)."
"Waste and Materials-Flow Benchmark Sector Report: Beneficial Use of Secondary Materials—Coal Combustion Products," U.S. Environmental Protection Agency, Washington, DC, Feb. 2008, 95 pp., http://circainfo.ca/members/documents/EPAWasteandMaterials-FlowBenchmarkReportFeb2008.pdf.

9 From 2001 to 2006, the Government of Canada's National Action Plan on Climate Change presented Federal Departments of Natural Resources, Industry, Public Works, Environment & Health, and industry stakeholders with opportunities to identify and develop emission-reduction strategies and practices.

10 NRMCA confirmed "ready mixed concrete forms the single largest market for fly ash" and that, "even so it can still offer the largest potential for increased fly ash utilization," confirming "34% of all ready mixed concrete was produced with straight portland cement... 56% was produced with fly ash as the only SCM."
Obla, K. H.; Lobo, C. L.; and Kim, H., "2012 NRMCA Supplementary Cementitious Materials Use Survey," *Concrete InFocus*, Fall 2012, pp. 16-18.

11 Mehta, P. K., and Walters, M., "Roadmap to a Sustainable Construction Industry," *The Concrete Specifier*, Jan. 2008, p. 50.

12 Bouzoubaa, N., and Foo, S., "Use of Fly Ash and Slag in Concrete: A Best Practice Guide," Materials Technology Laboratory, Jan. 2005, 46 pp., http://circainfo.ca/documents/UseofFAandSlaginConcrete-ICONPWGSCJan2005.pdf.

13 Weir, A., and Kennedy, D., "Fly Ash Forecast: Fair, Changeable, Increasingly Sustainable," *Ready Mix News*, V. 23, No. 1, May 2014, pp. 6-7, http://www.atlanticconcrete.ca/images/pdf/rmnspr14.pdf.

14 Goss, D., "Usage Declines May Signal Beginning of Troubling Trend," *ASH at Work*, Issue 2, 2010, pp. 14-17.

15 "Replacing part of the clinker with low-cost coal fly ash has recently emerged as a viable economical and ecological solution to balance material efficiency with environmental concerns. From a resource perspective, coal fly ash is still underutilized in the industry, while it is well known to be an excellent candidate to partially replace clinker," "Fly Ash is Critical for C-A-S-H," Concrete Sustainability Hub@MIT Research Profile Letter, Sept. 2010, http://cshub.mit.edu/sites/default/files/documents/9-2010%20CSHub-News-Brief%20%282%29.pdf.

16 "The Economic Impacts of Prohibiting Coal Fly Ash Use in Transportation Infrastructure Construction," American Road & Transportation Builders Association Transportation Development Foundation, Washington, DC, Sept. 2011, 131 pp.

17 Perkins+Will, "Fly Ash in Concrete," Nov. 2011, 54 pp.

18 Sachs, J. D., *The Price of Civilization: Economics & Ethics after the Fall*, Random House Canada, Toronto, ON, Canada, 2011, 336 pp.

19 Sachs, J. D., *The Price of Civilization: Economics & Ethics after the Fall*, Random House Canada, Toronto, ON, Canada, 2011, 336 pp.

20 "Human Influence on Climate Change Clear, IPCC Report Says," Sept. 2013, 3 pp., http://www.ipcc.ch/news_and_events/docs/ar5/press_release_ar5_wgi_en.pdf.

2014—offers a glimpse into the potential future of coal ash in the United States:

> "In recent years, emission reduction regulations, access to lower-priced, lower-emitting natural gas and investment in renewable energy sources have contributed to a decrease in coal-fired power generation in Canada, with a corresponding impact on coal ash production. Meanwhile, steady demand for coal ash [has recast] landfilled ash as a significant source of materials and minerals to supply diversifying markets…
>
> "Ash recovered from landfill offers social, economic and environmental benefits…that [traditional sourcing of] natural materials cannot…[filling] demand for natural resources… (i.e.: lime, sand, aggregate, metals and rare earths), reducing demand for resources from natural sources. In terms of energy demand and CO_2 emissions, ash recovery and processing requires significantly less energy, and generates significantly lower emissions, than traditional mining and processing of natural mineral resources."[21]

Meanwhile, the specter of declining availability is encouraging industry to manage and allocate ash like the high-demand, value-adding material it is. Just as chemical solutions are minimizing the impact of operational changes adopted to comply with legislated regulatory changes,[22] processes and technologies that facilitate use of landfilled ash are very much in process.[23] While use of coal ash in cement and concrete manufacture remains strong, new uses are proliferating: "high commodity prices are encouraging [extraction of] minerals, metals and rare earths from coal ash deposits [where] recovered ash can supply high-demand materials…to market more sustainably than traditional mining methods allow."[24]

2014 industry parameters paint a compelling canvas of opportunities and challenges for coal ash use:

- Our infrastructure is crumbling faster than our respective economies are recovering;
- Coal ash is recognized as key[25] to cost-effective, more sustainable concrete;
- Coal ash production is declining in Canada, and slated for reduction in the United States;
- Six years of legal uncertainty requires proponents' work to restore coal ash to its pre-Kingston status in design, purchasing, and performance specifications;
- CCPs' capacity to reduce atmospheric emissions AND sustain productivity is eclipsed by politically motivated assaults on the materials' "credibility";
- Government agency influence is diminished, yielding fewer influential voices to champion, never mind maximize, beneficial use.

As reasonable as it may sound to delegate the recycling of coal ash to the marketplace, history suggests there are potential drawbacks to doing so without the steadying influence of government collaboration:

> "markets systematically underprovide certain 'public goods,' such as infrastructure, environmental regulations, education and scientific research, whose adequate supply depends on the government."[26]

Judicious management of coal ash will support "public good" through more sustainable practice; EPA's 2000 and 2014 decisions bear this out. Despite agreement that coal ash in cement and concrete yields more durable infrastructure, current recycling rates—31% in Canada, 44.5% in the United States—suggest limits to the market's capacity to realize the full potential of our ash resources unaided because the majority of North American coal ash production is still being diverted to landfill.

Government support of the industry has historically proved effective: use rates increased under the U.S. government's Coal Combustion Products Partnership and Canada's National Action Plan on Climate Change. Both programs quantified compelling emission reduction[27] and other[28] sustainability benefits, offering the security of legal certainty required to realize CCPs' sustainability potential.

Given the capacity of CCP use to reduce emissions and reduce consumption of energy and natural resources in the manufacturing, transportation, construction, and mining sectors, and given the significance of our governments' challenges to demonstrate policy that redresses climate change, restoration of government involvement to maximize CCP use is eminently practical. Public support of CCP use will promote "sustainable industry development, whilst protecting the environment and

21 CIRCA, "Utilization of Coal Ash from Landfill," Apr. 2013, 2 pp., http://www.circainfo.ca/documents/Circa_FactSheet10_FINALUtilizationfromLandfill-03.pdf.

22 "Since 2010, Mercury emission reduction legislation required operational changes impacting Fly Ash characteristics, an issue with which the concrete industry is still grappling. The adoption of chemical additives to reduce carbon content in Coal Ash presented a new challenge, which industry has worked successfully to address. As industries' knowledge base has evolved, tremendous progress has been made to develop new technologies, proving that operational changes (like Powdered Activated Carbon) present temporary challenges that can be remedied and will be resolved. "
Weir, A., and Kennedy, D., "Fly Ash Forecast: Fair, Changeable, Increasingly Sustainable," *Ready Mix News*, V. 23, No. 1, May 2014, pp. 6-7, http://www.atlanticconcrete.ca/images/pdf/rmnspr14.pdf.

23 Robl, T., "The Utilization of Ponded Ash," University of Kentucky Center for Applied Energy Research, ACAA Winter Meeting, Feb. 2013.

24 CIRCA, "Utilization of Coal Ash from Landfill," Apr. 2013, 2 pp., http://www.circainfo.ca/documents/Circa_FactSheet10_FINALUtilizationfromLandfill-03.pdf.

25 "Fly Ash is a Critical Tool," Portland Cement Association, Skokie, IL, Nov. 2009.

26 Sachs, J. D., *The Price of Civilization: Economics & Ethics after the Fall*, Random House Canada, Toronto, ON, Canada, 2011, 336 pp.

27 "If Fly Ash were used as an SCM (Supplementary Cementing Material) at the prescribed limit, about 1.2 Mt of GHG emissions would be displaced. If the prescribed maximum were surpassed by 25% or 50%, associated impacts would be 1.6 or 1.9 Mt CO_2e, respectively."
"Analysis of Resource Recovery Opportunities in Canada and the Projection of Greenhouse Gas Emission Implications," Natural Resources Canada, Ottawa, ON, Canada, Mar. 2006, 343 pp., https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/mineralsmetals/pdf/mms-smm/busi-indu/rad-rad/pdf/rrd2-eng.pdf.

28 "Beneficial use of fly ash in concrete and FGD gypsum in wallboard results in positive environmental impacts…most significantly energy savings ($4.7 billion in 2007 energy prices, enough energy to power over 4 million homes for an entire year), water use reductions ($76.9 million in 2007 water prices, roughly equivalent to the annual water consumption of 61,000 Americans)…, avoided greenhouse gas (11.5 million tons of avoided CO_2 equivalent and [other] air emissions (30.3 million kilograms of avoided NO_x, and 23.9 million kilograms of SO_x)."
"Waste and Materials-Flow Benchmark Sector Report: Beneficial Use of Secondary Materials—Coal Combustion Products," U.S. Environmental Protection Agency, Washington, DC, Feb. 2008, 95 pp., http://circainfo.ca/members/documents/EPAWasteandMaterials-FlowBenchmarkReportFeb2008.pdf

human health—both of which are implicit in the community license-to-operate obligations for society today."[29]

Because cuts to coal-fired power generation were announced, attention to the Canadian government's approach to climate change has become increasingly critical. Prime Minister Stephen Harper's stated intention to work collaboratively with the United States on climate change suggests reciprocal Canadian measures are likely. Industry stakeholders' commitment to sustainability will determine how such change is managed. More than ever before, we are all stakeholders: just as recent history shows how change is increasingly driven by national and international legislation, daily news demonstrates the depth of public engagement on sustainability and the environment. Under these circumstances, restoration of government involvement to maximize use of CCPs is the sustainable choice. ❖

CANADA, PRODUCTION AND USE OF COAL COMBUSTION PRODUCTS (CCPs), 2010-2012 AVERAGE

	Fly Ash	Bottom Ash	Flue Gas Desulphurization Gypsum	Other (1)	Total CCPs
			(000 tonnes)		
PRODUCTION					
Produced	4,068	1,865	241	188	6,361
Disposed / Stored	2,962	1,613	1	187	4,763
Removed from Disposal	15	–	–	–	15
USE (DOMESTIC)					
Cement	396	169	2	35	603
Concrete / Grout	745	0	0	0	745
Mining Applications	79	0	0	0	79
Roadbase / Subbase	12	50	0	0	62
Wallboard	0	0	238	0	238
Other (2)	33	4	0	1	38
TOTAL USE	1,265	223	240	36	1,764
Individual Use Percentage	31	13	100	20	28

Source: Natural Resources Canada
January 15, 2014
(1) Circulating fluidized bed fly ash and bottom ash
(2) Includes waste stabilization and specialty uses such as mineral filler and flowable fill

29 Heidrich, C.; Feuerborn, H.-J.; and Weir, A., "Coal Combustion Products—A Global Perspective," *VGB Powertech*, V. 96, No. 12, Dec. 2013, pp. 46-52, http://www.vgb.org/vgborg/en/pt_12_2013.html.

Music City Welcomes WOCA

Nashville, TN, will be the site of the 2015 edition of the World of Coal Ash from May 4 to 7. Co-sponsored by the Center for Applied Energy Research at the University of Kentucky and the American Coal Ash Association, it is the premier event in North America for those interested in the beneficial use of coal combustion products. The event is held every 2 years and is expected to attract 600 attendees. The event opens with a short course on coal combustion products with instructors from the academic community and industry experts. Presentations begin on Tuesday, May 5. Over 100 presentations will be made over the course of the event. Over 50 exhibitors will be on hand to provide information on equipment and services to the beneficial use community. A welcome reception will be held on Tuesday. On Wednesday evening, a field trip to the famous Wild Horse Saloon is scheduled.

The Nashville area offers a lot to see and do. The downtown area is particularly vibrant with music, food, and sports. Broadway Street is the main street for the nightclubs. No trip to Nashville is complete without a visit to the Ryman Auditorium, the Mother Church of Country Music. The Grand Ole Opry is just a short drive away. Mark your calendar and be sure to make your hotel reservations early.

Photos courtesy of Nashville Convention & Visitors Corporation.

IN & AROUND ACAA

WASHINGTON, DC

ACAA officials and volunteers staffed a booth in January at the Transportation Research Board meeting, which annually attracts nearly 12,000 transportation professionals from around the world. Executive Director Thomas Adams is shown discussing coal ash use with conference attendees. ACAA volunteer Dr. Lisa Bradley provided coal ash-themed M&Ms as a conversation starter.

LEXINGTON, KY

The Center for Applied Energy Research and ACAA co-hosted an Ash Utilization Workshop in April that featured expert speakers from across the beneficial use industry. Among them, Dr. John L. Daniels, P.E., Associate Professor of Civil and Environmental Engineering at the University of North Carolina at Charlotte, presented information on how beneficial use of coal ash helps control costs, creates better products, and helps create a more sustainable community.

ALBUQUERQUE, NM

Barnes Johnson, Director of the U.S. Environmental Protection Agency's Office of Resource Conservation and Recovery, attended ACAA's winter meeting to brief ACAA membership on the results of the Agency's risk evaluation of fly ash concrete and synthetic gypsum wallboard. From left to right: ACAA Chair Lisa Cooper, Mr. Johnson, ACAA Vice-Chair Hollis Walker, and ACAA Past Chair Mark Bryant.

ASH ALLIES

American Road & Transportation Builders Association Champion for Coal Ash Reuse in the Transportation Construction Industry

American Road & Transportation Builders Association

Since 1902, the Washington, DC-based American Road & Transportation Builders Association's (ARTBA) mission has been crystal clear: "We are a federation whose primary goal is to aggressively grow and protect transportation infrastructure investment to meet the public and business demand for safe and efficient travel. ARTBA also provides programs and services designed to give its members a global competitive edge."

On behalf of its 6000+ members from the public and private sectors, ARTBA works to ensure its members' views and business concerns are addressed before Congress, the White House, federal agencies, the courts, the general public, and news media.

The number one reason why people join ARTBA is simple. They deliver results. That's their value proposition and it explains why industry firms and organizations make ARTBA a key part of their business strategy. Since 1990, federal investment in transportation construction programs has increased 50% more compared to federal outlays for general construction.

ARTBA consistently leads the charge and frames the surface transportation reauthorization debate on Capitol Hill. It advocates for expanded investments in highways, bridges, transit, airports, rail, and ports and waterways to meet the infrastructure challenges of today's global economy. The transportation construction industry ARTBA represents generates more than $380 billion annually in U.S. economic activity and sustains more than 3.3 million American jobs.

ARTBA has been a steady ally for the American Coal Ash Association (ACAA) in the ongoing effort to prevent the United States Environmental Protection Agency (EPA) from designating coal ash as a "hazardous substance." Over the past 5 years, ARTBA has provided multiple sets of regulatory comments, legislative testimony, and public statements documenting the essential role of coal ash in transportation construction and helping to preserve and improve the nation's infrastructure.

The most visible display of ARTBA's advocacy on the coal ash issue is the ARTBA Foundation's September 2011 study, "The Economic Impacts of Prohibiting Coal Fly Ash Use in Transportation Infrastructure Construction," which concluded "the cost to build roads, runways, and bridges would increase by an estimated $104.6 billion over the next 20 years if coal fly ash is no longer available as a transportation construction building material."

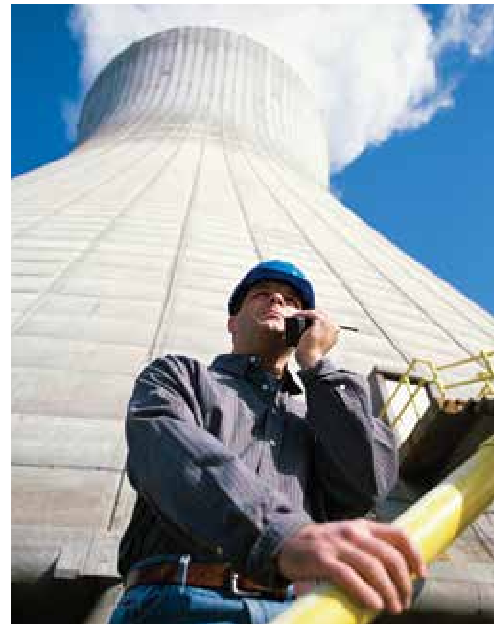
This breaks down to a $5.23 billion annual direct cost, including a $2.5 billion increase in the price of materials and an additional $2.73 billion in pavement and bridge repair work due to the shorter pavement and service life of other portland cement blends. To put this $5.23 billion figure in perspective, it is **almost $2 billion more per year than the federal government currently invests in the Airport Improvement Program and approximately 13% of the federal government's annual total aid to the states for highway and bridge work.**

The ARTBA Foundation study also explored how states would have to forego the potential additional benefits and savings of as much as $65.4 billion over 20 years derived from using fly ash in new, high-performance concrete pavements.

In addition to the economic impacts detailed in the ARTBA study, the transportation sector's use of coal ash is truly an environmental success story. According to EPA's own data, coal ash accounts for between 15 and 30% of the cement in concrete. Further, EPA has noted using coal ash at this level results in annual greenhouse gas (GHG) reductions in concrete production between 12.5 and 25 million tons and an annual reduction in oil consumption between 26.8 and 53.6 million barrels. Also, EPA has stated coal ash "generally makes concrete stronger and more durable," which "reduc[es] the need for future cement manufacturing and corresponding avoided emissions and energy use."

ARTBA's President & CEO Pete Ruane has more than 40 years of diversified experience in the economic development, transportation, construction, and national defense fields, and is known as the "dean of transportation lobbyists" on Capitol Hill. A decorated Vietnam veteran, he worked at the highest levels of the U.S. Department of Defense. He later spent 9 years as President and CEO of National Moving and Storage Association before assuming the top job at ARTBA in 1988.

At a time when discussions are beginning to occur on reauthorizing the nation's surface transportation program, ARTBA looks forward to continuing to work with ACAA and ensure EPA does not unnecessarily increase the cost of sorely needed transportation improvements which improve public health and safety by designating coal ash as a "hazardous substance." ❖



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ASH CLASSICS

A Long History for Structural Fill

"Ash Classics" is a recurring feature of ASH at Work *that examines the early years of the National Ash Association (NAA) and issues and events that were part of the beneficial use industry's defining years.*

The use of coal ash in engineered structural fills can be traced to the very origins of the beneficial use industry. A 1970 white paper by the ACAA predecessor National Ash Association shows that materials characterization and design for specific engineering purposes were chief considerations from the foundations of the practice. A 1982 "Ash in Action" newsletter prominently discusses the use of coal ash for road base on the Washington Dulles International Airport access road.

with compliments of

NAA NATIONAL ASH ASSOCIATION, INC.
1819 H Street, N. W.
Washington, D. C. 20006

Meeting
Preprint JPG-70-9

Fly Ash as a Structural Fill

A. M. DiGioia, M. ASCE and
W. L. Nuzzo, A. M. ASCE

ASME-IEEE Joint Power Generation Conference
ASCE Participating Society
Pittsburgh, Pa.
September 27-October 1, 1970 / $1.00
Nonmembers / $2.00

Complete copy of paper available at http://bit.ly/Y62pfZ

Dateline: Washington

NAA **ASH IN ACTION**

NATIONAL ASH ASSOCIATION, INC. SUITE 510, 1819 H. STREET, NW. WASHINGTON, D.C. 20006 (202) 659-2303

VOLUME I, ISSUE 2 FEBRUARY, 1982

COVEY'S CORNER: We really appreciate your support and enthusiasm for the first issue of Ash in Action. Your comments and suggestions are always welcome, and your Washington staff will continue to promote and support the interests of our industry all over the world.

Please remember, when requesting additional information from our staff, please refer to the AiA Volume and Issue numbers as well as to the article numbers of any items which interest you.

Ash Marketers, please be sure to take note of the article below on the new stretch of the Dulles Airport Access Road about to be put to bid. And we have just received a FLASH from the Department of Transportation: Don Graffe of the Federal Highway Administration has just announced that the contract for the stretch of the Dulles Access Road described in AiA's December, 1981 issue is being awarded to Cherry Hill Sand and Gravel Co., Jessup, MD on February 5, 1982, for 6" lime-fly ash-aggregate. Our congratulations to Cherry Hill!

Well, the time for the Sixth International Ash Utilization Symposium, March 7-10 is getting closer. It's really going to be an exciting and informative event and I'm looking forward to seeing all of you there.

Jim Covey

****

1. NEW DULLES AIRPORT SECTION TO BE BID - NAA Headquarters has learned that the Federal Highway Administration (FHWA) will release Section 3 of the Dulles Access Road for bids later in February. Bidding documents will specify 140,000 sq. yds. of 6" lime-fly ash-aggregate base (LFA). Bid dates and additional details will be available from NAA Headquarters as soon as they are released.

2. RCRA GUIDELINES - At a late-January U.S. Chamber of Commerce luncheon attended by John Gillis of NAA's Washington Staff, Environmental Protection Agency (EPA) Administrator, Ann Gorsuch discussed the status of the Resource Conservation &

Complete copy of newsletter available at http://bit.ly/1oKpkTd

2014 AMERICAN COAL ASH ASSOCIATION MEMBERSHIP DIRECTORY

These listings are organized into the following six membership categories:

▪ **Utility** ▪ **Marketer** ▪ **Specialty Marketer** ▪ **Associate** ▪ **Individual**

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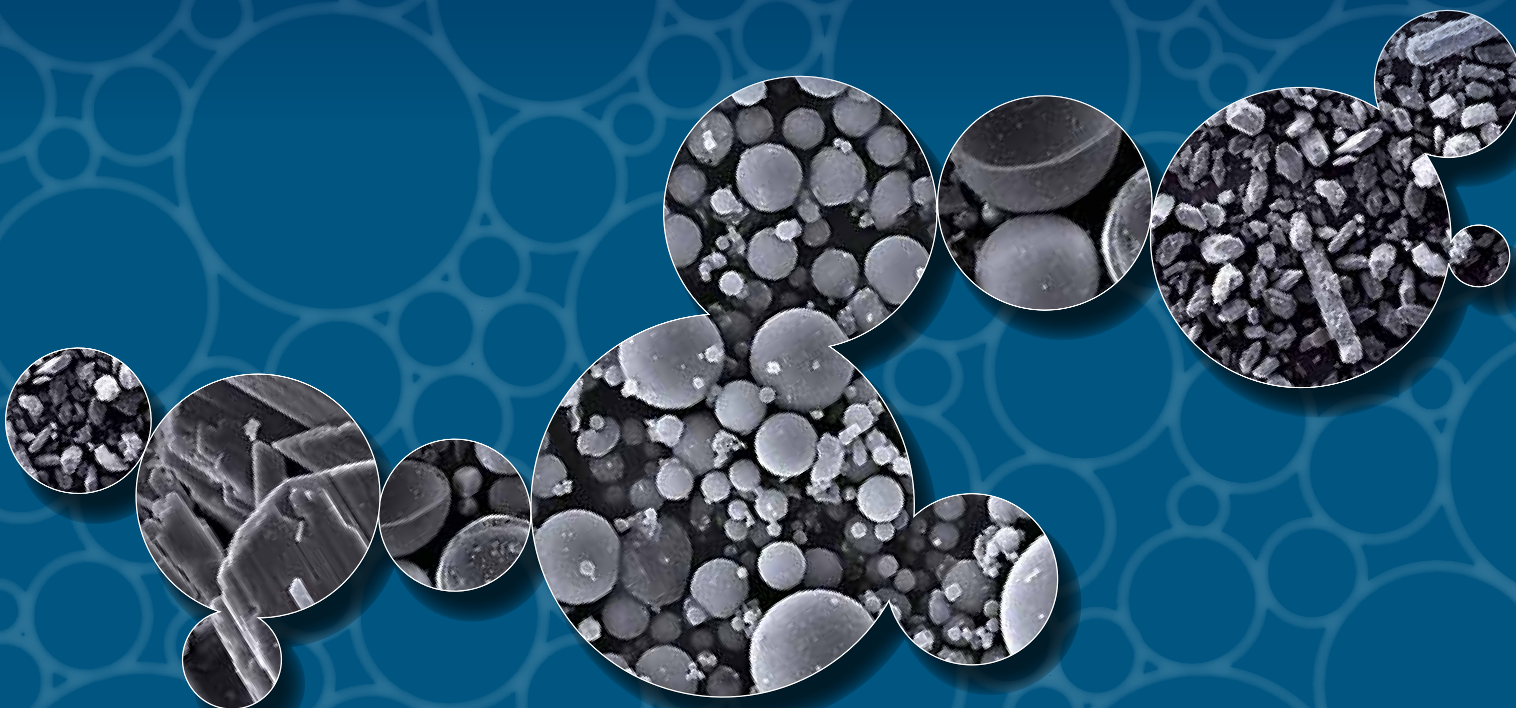

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Influence of Activator Solution Formulation on Fresh and Hardened Properties of Low-Calcium Fly Ash Geopolymer Concrete

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The effect of the composition of activator solutions on fresh and hardened properties of geopolymer concrete was investigated. Research variables included liquid sodium silicate product (DH, NH, and StarH), sodium hydroxide molar concentration (6, 10, and 14), and sodium silicate–to–sodium hydroxide ratio (1, 2, and 3). Response variables were compressive strength, corrosion resistance expressed as remaining compressive strength and mass loss, and flowability. Results were analyzed using Minitab statistical software. Findings suggest that activator solution formulation has a significant effect on the properties of the resulting geopolymer binder. The experimental design used was found effective in establishing the optimum activator solution formulation for a given fly ash stockpile to be used for an application with specific performance requirements.

Full paper available at: www.coalcgp-journal.org

Cordyline fruticosa Growth and Soil Microbial Quality with Topical Application of Coal Combustion By-Products Aggregates

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Coal combustion by-products aggregates (CCAs) are a solidified composite of fly and bottom ashes (2:1, by wt). Here, we assessed the feasibility of beneficial use of CCAs as a soil amendment or conditioner by conducting an outdoor experiment with *Cordyline fruticosa* (lucky plant) to determine its growth and soil microbial quality under the influence of topical CCA application (95 tons ha21). Enhanced growth of *C. fruticosa* with CCA application was noted, with respect to plant height, growth rate, leaf size, and leaf chlorophyll intensity. Soil dehydrogenase activity and total heterotrophic bacteria count were greater with topical CCA application, especially in the 5–15-cm layer, than in the control system without CCAs. The stimulated soil microbial quality due to the influence of CCAs was believed to be responsible, at least in part, for enhanced growth and health of *C. fruticosa*. Therefore, CCAs can be construed as beneficial as a soil amendment or conditioner for decorative plants such as *C. fruticosa*.

Full paper available at: www.coalcgp-journal.org

Quantifying the Benefits of Flue Gas Desulfurization Gypsum in Sustainable Wallboard Production

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Electric utilities produce more than 11.2 Mt of flue gas desufurization gypsum annually. Approximately 7.5 Mt are used in wallboard production. This paper examines the environmental and cost benefits associated with replacement of natural gypsum in wallboard with flue gas desulfurization gypsum.

A life-cycle analysis program was used to quantify the benefits of using flue gas desulfurization gypsum from electric power production in wallboard construction. Comparisons were made between energy consumption, water use, and greenhouse gas emissions associated with obtaining and processing virgin gypsum material and with flue gas desulfurization gypsum. The analysis considered wallboard produced with 100% natural gypsum or 100% flue gas desulfurization gypsum. From discussions with wallboard industry representatives, system boundaries were established that set resources associated with pre-drying flue gas desulfurization gypsum at the wallboard plant equivalent to those associated with milling and pre-drying virgin gypsum. Ultimately, gypsum mining was the only factor contributing to environmental differences between wallboard manufacturing using virgin gypsum and flue gas desulfurization gypsum. Additional impacts of landfilling the unused flue gas desulfurization gypsum was also considered using life cycle inventory for data generated from construction, operation, and maintenance costs for Subtitle D (non-hazardous municipal solid waste) landfills. In 2007, the United States utilized 7.5 Mt of flue gas desulfurization gypsum in wallboard production. An equivalent annual use of flue gas desulfurization gypsum as a replacement for mined gypsum in wallboard manufacture and the associated avoided landfilling of unused flue gas desulfurization gypsum results in a reduction of energy consumption by 1,200 TJ, water consumption by 18 GL, greenhouse gas emissions by 83 Mt CO_2e, and a cost savings of $49 to $64 million dollars. The associated reduction in energy consumption from using flue gas desulfurization gypsum in wallboard is commensurate with the annual energy use of 11,800 American homes, 58% of the annual domestic water use in Nevada, USA, and the removal of 11,400 American automobiles from the roadway.

Full paper available at: www.coalcgp-journal.org

Microstructural and Mineralogical Transformation of Hydraulically Disposed Fly Ash—Implications to the Environment

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Increasing amounts of coal are combusted annually to meet the ever-increasing energy demands. The inevitable by-products include

fly ash and saline effluents, which require acceptable disposal. The aim of this article is to compare the effect of hydraulic disposal with dry ash dumping. The results indicate that the former carries more environmental benefits based on the physical, chemical, and mineralogical aspects that were investigated.

Full paper available at: www.coalcgp-journal.org

Waste Classification of Slag Generated in a Pilot-Scale Entrained-Flow Gasifier

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Series of gasification tests have been completed in the pilot-scale entrained-flow slagging gasifier at CanmetENERGY using Canadian coals, oil-sand coke, and blends of these fuels to determine if the produced slags are nonhazardous in nature. Solid wastes generated during these tests were analyzed for their trace metals, crystallinity, and toxic constituent leaching tendency in an attempt to provide more insight into the possibility of disposal or by-product use of gasifier-produced solid waste. The gasification tests were performed at conditions representative of commercial gasifiers using a dry-fuel-feed configuration. The lower-volatility elements were found to partition between the slag and process-water solids (PWS) collected after gasification of the oil-sand coke. The less volatile group 1 elements tended to be enriched in both solid streams, whereas the slightly more volatile group 2 elements tended to exhibit higher enrichment in the PWS. Slag samples were found to be inert with regard to their leaching potential, and so these materials can be considered nonhazardous.

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Mineralogical Transformations in Coal Feedstocks during Conversion or Combustion, based on Packed-Bed Combustor Tests – Part 1: Bulk Coal and Ash Studies

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Mineralogical and inorganic geochemical studies have been carried out on composite samples of six different coarse-crushed (<120 mm) feed coals tested in a pilot-scale packed-bed combustor designed to simulate conversion and some fixed-bed combustion processes, and also on composite samples of the ashes produced. Six different coals were tested, with percentages of mineral matter (LTA yield) ranging from 25 to 47%. Quantitative XRD analysis shows that the low-temperature (oxygen-plasma) ash (LTA) of the individual coals contains 15-22% quartz, 48-64% kaolinite, and 2-7% calcite, 4% aragonite, and 3-12% dolomite. Small, but significant proportions of illite, mica, pyrite, titanium minerals (rutile, anatase), and aluminophosphate material (goyazite) are also found in some of the coal samples.

Bassanite, and in some cases gypsum, are found in the LTA of all the coal samples. These phases are thought mainly to represent artefacts derived from interaction of organically-associated Ca and S during low-temperature ashing. A lower percentage of these phases was observed in the LTA of the coal with the highest mineral matter (LTA) percentage, consistent with a lesser abundance of organic matter containing organically associated Ca and S in that particular sample.

The ash produced in the lower part of the packed-bed combustor from these coals, at temperatures up to 1250 to 1260 °C, contains 11-17% quartz, 11-32% mullite, 3-11% cristobalite, and 5-13% anorthite, along with 36-49% amorphous material. As might be expected, the mineralogy of this ash produced is related to the mineral matter in the feed coal used for each test. Although much of the quartz in the coal appears to be unreactive, some reacts to form cristobalite under the conditions in the combustor vessel; as a result the proportion of quartz + cristobalite in the ashes is close to that of quartz in the LTA of the respective feed coal samples. The clay minerals in the coal react to form mullite plus amorphous material, with the proportion of mullite in the ash being broadly related to the total proportion of clay minerals (plus mica where present) in the different feed coals.

Calcium, whether in carbonate phases or associated with the organic matter of the coal, appears to react with some of the aluminosilicate material released by changes in the clay minerals to form anorthite. Other Ca-bearing aluminosilicates, such as gehlenite and diopside, may also be produced. Small proportions of Ca not taken up in this way may form anhydrite and/or portlandite, although some may also be incorporated into the amorphous material. The proportion of anorthite and other crystalline Ca-bearing phases in the ash is therefore related to the proportion of Ca-bearing phases, including bassanite and gypsum as well as carbonates, in the LTA of the respective feed coal materials.

Pyrite in the coal appears to form iron oxide minerals, with hematite as the main crystalline iron-bearing phase in the packed-bed combustor system. Although the proportions are low and other sources of iron may also be involved, the proportion of iron oxide minerals in the ash is broadly related to the proportion of pyrite in the LTA of the coal samples.

The chemical composition of the ashes from the packed-bed combustor, with the exception of one sample, are very similar to the chemical composition of the laboratory-prepared (815 °C) ashes from the respective feed coal samples, after both are normalised to remove the dilution effects of the loss-on-ignition and SO_3 components. The base/acid ratios obtained for the combustor ashes are very similar to the base/acid ratios obtained from chemical analyses of the laboratory-prepared (815 °C) ashes for the respective feed coals. This suggests that the reaction process is essentially iso-chemical in nature from the mineral matter point of view.

This study has indicated a number of quantitative links between the mineral matter in a range of feed coals and the mineralogy of the ash produced by the packed-bed combustor process. In particular the proportion of anorthite and other Ca-bearing phases in the combustor ash, which appears to have a bearing on sintering and slagging behaviour, is related mainly to the percentage of Ca-bearing carbonates in the mineral matter of the feed coals. The study has also shown that quartz in the coal is partly transformed to cristobalite under packed-bed combustor conditions. Although a significant scatter is involved, the proportion of iron oxide phases in the ash

is also broadly related to the proportion of pyrite in the feed coal mineral matter.

Although there may be some technological differences between the reactor and full-scale utilisation facilities, the results of the study provide an improved basis for understanding the mineralogical changes associated with ash formation during coal conversion or combustion processes. They also provide a basis for the prediction of ash characteristics, including the potential for clinker development, based on integrating the mineralogical properties with the bulk chemistry of the feed coal used in such utilization systems.

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Mineralogical Transformations in Coal Feedstocks during Carbon Conversion, based on Packed-Bed Combustor Tests – Part 2: Behaviour of Individual Particles

Ratale H. Matjie, Colin R. Ward, and Zhongsheng Li

Individual particles of coal and non-coal material from the upper and lower parts of a pilot-scale packed-bed combustor bed, designed to simulate conversion or combustion processes, were subjected to an integrated program of mineralogical and inorganic geochemical analysis. The main objective of the study was to evaluate the reactions that may occur during carbon conversion at a particle-by-particle scale, and thus gain an improved understanding of the contributions from the different types of particles in the feedstock to the overall ash formation process during utilisation of coarse-crushed coal materials.

Coarse-crushed coal feedstocks inherently contain separate fragments, ranging from carbon-rich material (coal) to mineral-rich non-coal material (stone), due to the heterogeneous nature of the coal beds from which they are mined. Analysis of hand-picked coal and stone particles from six different Highveld feedstocks, crushed to <120 mm, has shown that the two different groups have quite different mineralogical and chemical properties. The carbon-rich particles typically contain higher proportions of carbonate minerals (calcite, dolomite) than the stone fragments; the stone fragments typically contain a greater abundance of quartz and illite, and, in some cases, also contain abundant detrital feldspar minerals such as microcline.

The mineral assemblages in these two types of particles also respond in different ways to the high temperatures (up to 1260 °C) reached in the combustor column. In the lower (highest-temperature) part of the packed-bed combustor the clay minerals (especially kaolinite) in both the carbon-rich and mineral-rich fragments transform to mullite, cristobalite, and amorphous material. Quartz may also react to form cristobalite under these conditions. Pyrite in the carbon-rich (and in some cases in the mineral-rich) fragments reacts under reducing conditions to form pyrrhotite and/or troilite, with further breakdown of these minerals forming hematite and other iron-oxide phases.

The carbonate minerals may undergo solid-state reactions with the clay mineral residues to form a variety of calcium silicate phases, including anorthite, gehlenite, akermanite, and diopside. The $CaCO_3$ polymorph vaterite may also be formed in some cases. Bassanite, together in some cases with anhydrite or gypsum, is also found in the low-temperature oxygen-plasma ash (LTA) residues of the heated but still carbon-rich (char) particles. As with the same phases in the LTA of the feed coals, the bassanite and gypsum may represent artefacts of low-temperature ashing; however, in the char they may also represent products of reaction between CaO from decomposed carbonates and S released from carbonised organic matter within the combustor system.

Bonded aggregates (clinkers), made up of heated stone and/or char particles bound together by solidified glassy (molten) material, were formed in the lower parts of the combustor column. Higher proportions of anorthite, amorphous material, and, possibly, cristobalite are associated with the clinkers, relative to the unbonded heated stone fragments. The difference probably reflects the nature of the bonding material. The fused material bonding the particles together to form the clinkers was probably derived from melting of the Ca-rich ash left after removal of organic matter from the carbon-rich particles in the feed coal. Anorthite and mullite crystallised from the melt on cooling, after the melt had flowed around the more solid stone and char fragments remaining in the ash bed.

Mineralogical analysis of individual carbon-rich and mineral-rich fragments, and also of bonded aggregates (clinkers) from different zones of the packed-bed combustor, therefore provides a useful supplement to study of composite feed coal and bulk ash materials, helping significantly to understanding the mineral reactions that take place under high-temperature conditions. Melting of Ca-rich ash from the carbon-rich particles, for example, with a high B/A ratio, represents a key process in clinker formation. Hand-picked samples of the different coal components in such a coarse-crushed feedstock can encompass the mineral associations and interactions that occur at the individual particle scale, giving a better insight into the heterogeneous nature of the coal feed and resulting ash product.

Study of individual coal and ash particles can be used to complement more conventional approaches based on whole-coal and homogenised ash materials, and provide a more comprehensive basis for feedstock management in relation to the resulting ash properties. Most importantly, it is shown in this study that mineralogical changes during coal utilisation do not take place at a bulk level encompassing the entire feedstock, but occur in single particles where different mineral assemblages may respond in different ways to the imposed reaction conditions. Ca-rich particles that give rise to ash with a low melting point, for example, provide the bonding material in the present study that leads to clinker formation.

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Potential Indoor Air Exposures and Health Risks from Mercury Off-Gassing of Coal Combustion Products (CCPs) Used in Building Materials

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Coal combustion products (CCPs), including coal fly ash (CFA) and flue gas desulfurization (FGD) gypsum, have gained accepted use as substitutes for traditional substances in building materials. The presence of trace metals and other contaminants in CCPs has led to concerns regarding possible human exposures and potential health risks associated with their beneficial use in products such as building materials. However, despite these concerns, few qualitative or quantitative risk assessments addressing CCP beneficial use applications have been conducted. Recognizing the need for such scientific analyses, US EPA announced in late 2011 its plans to conduct a health risk assessment covering various CCP beneficial use applications.

Specific concerns have been raised regarding the fate of mercury (Hg) in CCP building materials, given its volatility and expectations that levels in CCPs will increase with continued efforts to improve Hg capture from stack flue gases. Risk assessment offers a well-established, objective framework with which to determine whether Hg off-gassing from CCP building materials could result in human exposures of health concern. We thus conducted a screening-level human health risk assessment to estimate potential inhalation risks from indoor air exposures to Hg for multiple CCP utilization scenarios: (1) FGD-gypsum wallboard used in a school classroom or home, and (2) CFA concrete blocks used in a school classroom. Mercury off-gassing rates were estimated using published experimental data from laboratory studies, and indoor air Hg concentrations and exposure levels representative of high-end and more typical exposure conditions were predicted using a mass balance indoor air model and conservative (i.e., health-protective) assumptions regarding building characteristics (*e.g.,* material loading ratios, air exchange rates) and exposure parameters (*e.g.,* exposure times, frequencies, and durations).

Even using parameters intended to overstate potential exposures, predicted indoor air Hg concentrations were typically below background indoor Hg levels. With calculated hazard quotients (HQs) that ranged from 0.00004 to 0.016, predicted indoor air Hg concentrations were well below established inhalation toxicity criteria (Figure 1). Our risk assessment thus indicates that Hg off-gassing from CCPs in concrete and wallboard building materials is unlikely to result in indoor Hg exposures of potential health concern. Additional studies are needed to further characterize Hg off-gassing rates from CCP-containing building materials and to monitor any changes to Hg levels in CCPs, but this assessment provides support for a large margin of safety between worst-case indoor air Hg exposures associated with CCP-containing building materials and potential adverse health risks.

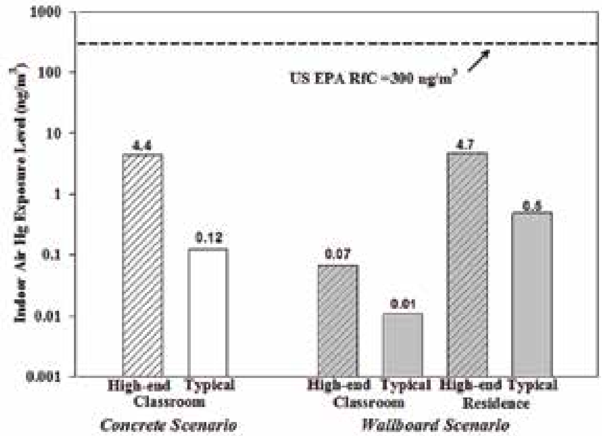

Figure 1. Comparison of time-adjusted estimates of indoor air exposure levels of Hg off-gassed from CCPs used in concrete and wallboard with the US EPA reference concentration (RfC) for elemental Hg (note the log-scale of the y-axis)

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Scale-Up Design and Erosion Studies of Bottom Ash in Pneumatic Conveying System

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Pneumatic conveying characteristics and scale-up studies of the bottom ash from three thermal power plants, i.e., M/s Orissa Power Generation Corporation (M/s OPGC), M/s Indian Metals & Ferro Alloys Ltd. (M/s IMFA), and M/s Jindal Stainless Ltd. (M/s JSL), were carried out in a pneumatic conveying test rig at the Institute of Minerals and Materials Technology, Bhubaneswar, Odisha, India. A minimum conveying line inlet air velocity of approximately 18–25 m/s was required for M/s OPGC, M/s IMFA, and M/s JSL bottom ash. The erosion rate of M/s OPGC and M/s JSL bottom ash was less in cast-iron bend compared with mild-steel bend, but for M/s IMFA the erosion rate was high and similar for both types of bends. Scale-up design was used to determine the variation in pressure drop and phase density at constant mass production flow rate in plant scale. Particle degradation size distribution studies also were carried out after conveying 2 t of bottom ash out of a total conveying of 16 t for each source of bottom ash.

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Effects of Coal Combustion Byproduct Encapsulated Ammonium Nitrate on Wheat Yield and Uptake of Nitrogen and Metals

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As a result of the use of ammonia nitrate (AN) in the bombing of the Alfred P. Murrah Federal Building in Oklahoma, regulations have been proposed on the sale and shipping of AN fertilizer in the United States, with the potential of restricting its use by farmers. Consequently, research is being conducted to reduce the explosive effects of AN by encapsulating it with coal combustion byproducts, including class C fly ash (FAC), class F fly ash (FAF), and flue gas desulfurization gypsum (FGD-gypsum).

Of the approximately 65 Mg of fly ash and 21 Mg of FGD-gypsum produced annually in the US, only a small fraction is used in agriculture. Coal byproduct encapsulated ammonia nitrate (CBEAN) could be a source of N fertilizer for farmers; however, potential metal uptake from soil amended with CBEAN has not been fully investigated. The objective of this study was to determine the effects of fertilization with CBEAN on wheat yield and uptake of N and metals.

Ammonium nitrate fertilizer encapsulated with FAC, FAF, or FGD-gypsum was obtained from Dr. Darrell Taulbee, University of Kentucky Center for applied Energy Research. The encapsulated AN fertilizers, as well as an unencapsulated AN control, were mixed with 2 kg of a low N soil at rates of 56 and 112 kg ha^{-1} and planted with hard red spring wheat (*Triticum aestivum L.*). Plants were grown in a growth chamber and fertilized with P and K of as required. Plants were harvested at the boot stage and at maturity for grain and straw.

Biomass yield at the boot stage was significantly higher in the FAC treatment, compared to the unencapsulated control, for both application rates. Nitrogen application increased wheat grain and strew yield compared to the control. Grain and straw yields were significantly higher in the encapsulated AN treatments only at the high application rate. Grain yields at the high application rate were 9.1, 10.8, 10.4, and 11.2 g for the AN, AN+FAC, AN+FAF, and AN+FGD-gypsum treatments, respectively.

Encapsulation of AN did not significantly affect N concentration of wheat biomass, grain, or straw.

Encapsulation of AN did not significantly affect the concentrations of As, Cu, Mn, and Zn in wheat biomass, grain, or straw. Wheat biomass Ca concentration at the boot stage was slightly elevated, compared to the unencapsulated control, in some of the encapsulated treatments at the high rate of application.

Soil extractable nitrate and ammonium concentrations were not significantly affected by AN encapsulation or application rate at either the boot stage or the grain stage harvests.

Biomass, grain, and straw yields for wheat plants fertilized with three types of coal byproduct encapsulated ammonium nitrate were higher or equal to those of plants fertilized with unencapsulated ammonium nitrate. The N concentrations of wheat biomass and grain in the encapsulated treatments were greater than or equal to those of the unencapsulated control. In this pot study, coal byproduct encapsulated ammonium nitrate fertilizer was as effective as unencapsulated ammonium nitrate for wheat growth, with no significant increase in plant metal concentrations. However, further field studies are needed to verify these findings.

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Fouling Intensity of Three Indian Coals

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Indian power sector is dominated by coal-fired thermal power plants which address 70% of domestic electricity needs and 60% of commercial energy needs. Out of 253 Gt of coal reserves in India, 89% are non-coking coal having 40 – 45% ash content by weight. Hence, it is imperative to study fouling intensity of Indian coals in order to effectively use high-ash coals without affecting the normal functioning of boilers, and to schedule periodic maintenance of the boilers. Three Indian coals (Coal 1 (lignite), 2 (bituminous), 3 (bituminous)) of varying ash content, carbon content, and calorific values were selected for this study, along with one coal (Coal 4) having less ash content (Table 1). Inertial force was considered to be dominant in transporting fly-ash particles to the surfaces, and the presence of liquids, condensed from the flue gas, was considered the main factor in holding the impacting ash particles together. Chemical equilibrium calculations were performed to quantify the condensable alkali salts, and eutectic formation was incorporated to accurately predict the condensation onset temperature. Furthermore, by including the binary eutectic, it is observed that the condensation onset temperature is reduced from ~1200 K to ~890 K. With that information, the self-regulated deposit growth model developed by Rosner and Nagarajan (1987) was adopted to simulate deposit growth. By applying energy conservation principles, the deposit surface temperature was calculated during its growth. Figure 1 shows deposit thickness versus time for 8 hours for a 210 MW power plant. At end of the eighth hour, Coal 2 shows highest deposition thickness of ~17 cm. Despite having low-ash content, the deposit thickness associated with burning Coal 1 is comparable o that corresponding to Coal 3. This is due to Coal 1 having a lower carbon content compared to Coal 3. The deposit thickness of Coal 4 was the least with thickness of ~1.5 cm. Based on this study, the following ranking has been assigned to coals in terms of their fouling tendency:

Coal 2 > Coal 3 > Coal 1 > Coal 4

Hence, a simple simulation procedure may be applied in power plants to rank the coals, and accordingly schedule boiler maintenance to remove the fouling deposit.

Table 1. Proximate analysis of select coals and their ash composition

	Coal 1	**Coal 2**	**Coal 3**	**Coal 4**
	(Irdi et al., 1993)	(Irdi et al., 1993)	(Roy, 1940)	(Senior et al., 2000)
Proximate Analysis (wt %)	Basis 100%			
Fixed carbon	35.1	34.7	56.34	61.99
Moisture	14.9	4.3	0.8	1.44
Ash	7.0	37.6	18.1	7.01
Volatile matter	rest	rest	rest	rest
Heating value (MJ/kg)	21.3	18.8	25.1	30.5
Ash composition (wt%)	Basis 100%			
Al2O3	15.3	23.3	22.54	22.87
CaO	14.7	1.4	2.58	1.84
Fe2O3	5.5	11.4	10.10	19.18
K2O	-	1.7	1.48	1.53
MgO	3.1	0.5	2.58	0.60
Na2O	0.9	0.1	0.30	0.32
SiO2	32.0	54.7	57.61	42.92
TiO2	2.3	1.3	1.52	1.71
SO3	-	-	0.25	-
From Ultimate Analysis				
S	1.9	0.5	-	1.64

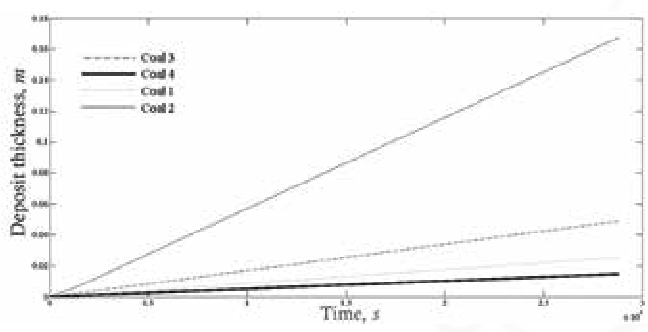

Figure 1. Deposit thickness as a function of time (up to 8 hours) for four selected coals for a 210 MW power plant running with 34% efficiency.

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A Note on the Occurrence of Yttrium and Rare Earth Elements in Coal Combustion Products

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There is an international need for a variety of lanthanide elements (rare earth elements, or REEs) in modern electronic and related components. This has led to a desire to broaden production from both previously productive locations and to expand production to new sources, possibly including coal-derived fly ash. The concentration of lanthanides in coal-combustion fly ash depends on a number of factors, one of the most important being the concentration of the elements in the feed coal. Unlike some elements, such as Zn and As, the REE concentration is largely not a function of element volatility. In this study, we review the concentrations of REEs in a power plant burning a variety of coals. Additionally, a power plant burning 2–3% tires in a cyclone boiler and a plant burning 30% pet coke were also investigated. In general, the Yttrium + REE concentrations do not systematically vary between electrostatic precipitator rows. However, the light REE/heavy REE ratio (LREE/HREE) generally decreases with a decrease in flue gas temperature. The element partitioning responsible for the LREE/HREE decrease is not fully understood.

Book Review: The John Zink Hamworthy Combustion Handbook, 2nd edition, Volume 1: Fundamentals

Edited by Charles E. Baukal, Jr., CRC Press, Boca Raton, FL, 2013.

The information on combustion technology is still not completely explored for each and every aspect of the combustion process. Industrial applications of the combustion process suffer from many challenges. Oil refining, power generation, and chemical process industries have stringent controls for air pollutant emissions resulting from the combustion process, and have been facing environmental and fuel-consumption issues in addition to the costs, that need to be addressed. The complete determination of these components requires the understanding of the combustion process. These include the fundamental concepts and detailed information on heat transfer, burners, kinetics, and the complex reactions that occur during the process.
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Full paper available at: www.coalcgp-journal.org

Geotechnical Characterization of Clinker-Stabilized Fly Ash–Coal Mine Overburden Mixes for Subbase of Mine Haul Road

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India is expecting to generate more than 2, 50, 000 MW during 12th five year plan period. The coal production would be 1000 MT per year. Opencast mining plays a major role in meeting the demand of fossil fuel for thermal power generation. Mine activities have to be expanded to meet this demand. It would lead to use of large capacity haul trucks. Carrying capacity of trucks/dumpers used in opencast mines has grown from 10 T to 200 T in recent years, with higher capacity being considered at places. Introduction of large capacity haul trucks demands well-designed haul roads. At present design of new haul roads is based on past experience and empirical methods. Opencast mines displace large amount of overburden as waste material.

The sub-grade, sub-base and/or base of haul road typically uses those overburden materials. This investigation wants to focus on replacing a part of overburden material with another suitable and better material. There are about 170 opencast coal mines and many are near to thermal power stations. Problems associated with vehicular breakdown and poor performances as well as low morale work force of manpower have been attributed to the poor condition of haul road. The current fly ash production is about 180 MT and will rise to about 600 MT by 2030. The usage percentage of fly ash is about 50% leaving the rest as plant waste occupying huge land area and creating environmental problems. Dumped fly ash adversely affects land, air and water resources. So its gainful bulk utilization is a major challenge to India's growing power sectors.

The investigation has characterized fly ash, mine overburden material as well as clinker. Geotechnical properties of untreated fly ash, mine overburden, fly ash-mine overburden mixes and clinker treated fly ash-mine overburden mixes were determined. Clinker percentage, curing period as well as fly ash percentage were observed to have strong influence on the strength parameters of the developed FCMs. The best material obtained was 62% FA+30% O/B+8% CL. Ultrasonic pulse velocity measurement was carried out to confirm the obtained UCS values.

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Chemical weathering and mobility of inorganic species in dry disposed ash: An insight from geochemical fractionation and physicochemical analysis

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The burning of low-grade coal produces vast amount of ash and other solid byproducts. In South Africa, coal combustion byproducts undergo disposal on land as dry heaps or slurried to dams. In this study, the geochemical partitioning, transport, and mobility of elements in dry disposed ash dumps were investigated using a modified sequential extraction scheme. The chemical and mineralogical compositions of 50 drilled core samples were investigated by X-ray fluorescence (XRF), inductively coupled plasma mass spectrometry (ICP-MS) and X-ray diffraction (XRD). Ternary plots of major elements as determined by XRF showed that the 15-year-old and 2-week-old dry disposed ashes are sialic, and the 4-year-old ash cores are sialic and ferrocalsialic. The variation in chemical compositions and degree of chemical weathering are ascribed to differences in the chemistry of feedstock coals and ash/water/CO_2 interaction chemistry. The relationship between SiO_2 and chemical index of alteration (CIA) showed moderate to high degree of weathering. Multivariate statistical analysis revealed the subtle chemical alteration differences and disparity in dissolution of major components of fly ash. The pH profile of the cores indicate that contact with atmosphere and consequent ingress of CO_2, leaching by rainwater and point of saturation has a great effect on the chemical weathering of the dry disposed fly ash. XRD analysis of two weathered drilled core samples taken from 4 m depth intervals showed the presence of calcite. The chemical interaction of fly ash with the atmosphere, ingress of CO_2 will ultimately lead to reaction with the buffering components such as CaO and subsequent conversion into calcite. The results obtained from modified geochemical partitioning scheme revealed the relative enrichment and depletion in the inorganic elements at various depth sections of ash dump (Tables 1&2). This is attributed to chemical interaction of fly ash with ingressed CO_2 from the atmosphere, pore water pH, leaching by percolating rain water, fluctuation in water level (i.e. weathering over time), heterogeneity in fly ash, continuous irrigation of fly ash by high saline effluents, and fresh water.

Table 1: Relationship of major elements in different solubility with depth of dry disposed ashes

Spearman's correlation (Only correlations that are significantly different from 0 at the 0.01 level)											
Obs	Age	Solubility	Variable	Al	Si	K	Na	Ca	Mg	Mn	Fe
1	4	Carbonate	Depth	-	-	-	-	-	-	0.60	-
2	4	Fe and Mn oxides	Depth	-	-	-	-	-	-0.65	-	0.67
3	4	Residual	Depth	-	-	-	-	-	-	-	-
4	15	Carbonate	Depth	-	-	0.57	-	-0.61	-	-	-
5	15	Exchangeable	Depth	-	-	-	-	-	-	-	-0.56
6	15	Fe and Mn oxides	Depth	-	-	-	-	-	-	-	-
7	15	Water soluble	Depth	-	-	0.63	-	-	-	0.71	-
Probability (p-values)											
Obs	Age	Solubility	Variable	PAl	PSi	PK	PNa	PCa	PMg	PMn	PFe
1	4	Carbonate	Depth	-	-	-	-	-	-	0.0031	-
2	4	Fe and Mn oxides	Depth	-	-	-	-	-	0.001	-	0.0007
3	4	Residual	Depth	-	-	-	-	-	-	-	-
4	15	Carbonate	Depth	-	-	0.0058	-	0.0028	-	-	-
5	15	Exchangeable	Depth	-	-	-	-	-	-	-	0.0068
6	15	Fe and Mn oxides	Depth	-	-	-	-	-	-	-	-
7	15	Water soluble	Depth	-	-	0.0016	-	-	-	0.0002	-

Table 2: Relationship of trace elements in different solubility with depth of dry disposed ashes

Spearman's correlation (Only correlations that are significantly different from 0 at the 0.01 level)										
Obs	Age	Solubility	Variable	As	Se	Mo	Cr	Pb	B	
1	4	Carbonate	Depth	-	-	-	-	-	-	
2	4	Fe and Mn oxides	Depth	-	-	-	-	-	-	
3	4	Residual	Depth	-	-	-	0.702	-	-	
4	15	Carbonate	Depth	-	-	-	-	-	-	
5	15	Exchangeable	Depth	-	-	-	-	-	-	
6	15	Fe and Mn oxides	Depth	-	-	0.57	-	0.72	-0.60	
7	15	Water soluble	Depth	-	-	-	-	-	-	
Probability (p-values)										
Obs	Age	Solubility	Variable	PAs	PSe	PMo	PCr	PPb	PB	smallp
1	4	Carbonate	Depth	-	-	-	-	-	-	0.0038
2	4	Fe and Mn oxides	Depth	-	-	-	-	-	-	0.0007
3	4	Residual	Depth	-	-	-	0.0075	-	-	0.007
4	15	Carbonate	Depth	-	-	-	-	-	-	0.003
5	15	Exchangeable	Depth	-	-	-	-	-	-	0.007
6	15	Fe and Mn oxides	Depth	-	-	0.0061	-	0.0002	0.0034	0.0002
7	15	Water soluble	Depth	-	-	-	-	-	-	0.0002

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Location of Cerium in Coal-Combustion Fly Ashes: Implications for Recovery of Lanthanides

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Given the worldwide demand for rare earth elements (REEs) in modern electronics, all potential sources of the REEs should be investigated. Coal-combustion fly ash represents a potential source of REEs. Fly ashes, derived from the combustion of coals from Kentucky in the United States and Jungar in China, were examined by wavelength-dispersive spectrometry electron microprobe analysis of epoxy-bound polished pellets. From previous studies, it was known that the REEs did not show any enrichment relative to flue gas temperature at the point of collection or to the particle size, that is, external surface area, of the particles. Cerium, the most abundant of the REEs in these fly ashes, was used as a proxy for the entire suite of REEs. For fly ashes from both sources, Ce is disbursed throughout the glassy fly ash particles. For fly ash processing with respect to the recovery of REEs, this implies that the entire particle must be leached to maximize the element recovery.

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Chemical partitioning and mobility of trace elements in dry disposed weathered ash conditioned with high saline effluents

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The mobility of inorganic elements in the ash dump due to chemical interaction of weathered dry disposed ash conditioned with high saline effluents with ingressed CO2 from atmosphere and percolating rain water was investigated. Drilled ash core samples collected from the weathered dry disposed ash dump at a South African coal burning power station were characterized using X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses. A modified sequential extraction (SE) procedure was selected to determine the mineralogical association of the investigated element in the 1-year-old drilled ash cores. XRD revealed the major fly ash mineral phases to be quartz and mullite. Other minor phases included hematite, lime, calcite, anorthite, mica and enstatite. The presence of minor quantities of mica and calcite in the weathered ash cores is attributed to carbonation process due to over time reduction in pore water pH. The 2-week-old ash cores are sialic in chemical composition (i.e. essentially Al and Si). On the contrary, the 1-year-old ash core samples were both sialic and ferrocalsialic in chemical composition (i.e. essentially Fe, Ca, Al and Si) which could be ascribed to indiscriminate dumping of Fe-catalyst. The chemical index of alteration (CIA) and chemical index of weathering (CIW) are both suggesting relatively high degree of weathering. CIA and CIW in the ash cores depend on the pore water pH, leaching rate, carbonation process, and possibly the conversion of alkali and alkali earth metals to carbonates. Multivariate analysis results suggest that the major oxides and carbon percent show differences and variables that have greater contribution to 1-year-old ash cores differentiation (Table 1). The decreasing response of As, Mo, Cr, and Pb with depth suggest immobility attributed to co-precipitation with Fe and Mn oxide phase of the ash core samples (Table 2). On the other hand, the increasing response of Pb, Mo and B in carbonate fraction with increasing depth suggests mobility due to weathering (Table 2) as revealed by leaching/ flushing of soluble major chemical phases (i.e., CaO and Na_2O). The relative mobility of trace elements in the 1-year-old ash cores are influenced by over time reduction in pore water pH.

Table 1: Varimax Rotated Factor Loadings Matrix and Communalities Obtained from Principal Component Analysis for the Studied Major Elements in the ash core samples

Variables	Comp. 1	Comp. 2	Comp. 3	Communalities
SiO_2	-0.99			0.99
CaO	0.95			0.85
P_2O_5	0.89			0.90
SO_3	0.79			0.80
Na_2O	0.79			0.80
LOI	0.77			0.97
TiO_2	0.75	0.60		0.81
Fe_2O_3		0.94		0.85
Al_2O_3		0.90		0.94
MnO		0.80		0.92
K_2O			0.92	0.78
MgO			-0.83	0.35
% C		-0.53		0.92
EV	5.73	3.64	1.51	
VAR (%)	44.10	28.01	11.65	
CVAR (%)	44.10	72.10	83.75	

Table 2: Relationship of major elements in different solubility with depth of dry disposed fly ashes

Spearman's correlation (Only correlations that are significantly different from 0 at the 0.01 level)										
Obs	Age	Solubility	Variable	As	Se	Mo	Cr	Pb	B	
1	1	Carbonate	Depth	-	-	0.57	-	0.58	-	
2	1	Exchangeable	Depth	-	-	-	-	-	0.55	
3	1	Fe and Mn	Depth	-0.83	-	-0.74	-0.71	-0.58	-	
Probability (p-values)										
Obs	Age	Solubility	Variable	PAs	PSe	PMo	PCr	PPb	PB	small p
1	1	Carbonate	Depth	-	-	0.0032	-	0.0025	-	0.0025
2	1	Exchangeable	Depth	-	-	-	-	-	0.0095	0.00107
3	1	Fe and Mn	Depth	<.0001	-	<.0001	0.0002	0.0047	-	2.1E-06

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