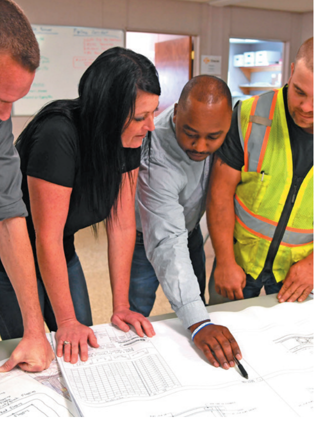



COST-EFFECTIVE ASH BENEFICIATION TECHNOLOGY

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ABSTRACT:

Currently, coal fly ash with a loss on ignition (LOI) above 6% does not meet ASTM C-618 specification. Additionally, coal fly ash with ammonia content above 100 ppm can cause health concerns for concrete workers due to off-gassing of the ammonia when mixed with alkaline materials. Also, many cement kilns have stringent guidelines on total mercury input, sometimes limiting the beneficial use of fly ash.

To increase supply of marketable fly ash to concrete producers nationwide, the MP618™ Multi-Process fly ash thermal beneficiation technology can reliably and continuously process fly ash to:

- **Reduce LOI to < 3%**
- **Reduce ammonia content to < 60 ppm**
- **Reduce mercury to < 100 ppb**
- **Reduce activated carbon and moisture**

Charah Solutions' proven MP618 technology allows for beneficiation of both wet and dry fly ash and offers important advantages over competing technologies. Specifically, it has a significantly lower cost profile, an efficient footprint with self-contained environmental controls that can be deployed in months versus years and a modular design that can be scaled up or down to increase production based on market demand.

With the functionality to process both wet and dry fly ash, the MP618 technology can be installed at operating power plants, non-operating power plants or off-site, regardless of whether the fly ash is current production or legacy ash stored in ponds or landfills. The technology also allows for the processing of kiln dust to remove mercury for emissions regulations compliance.

In addition, the MP618 process delivers a marketable concrete grade or cement kiln-friendly product from existing coal fly ash streams as a stand-alone process not required to be placed at a host utility. Finally, MP618 technology separates and isolates heavy metals, such as mercury and arsenic, particularly for cement kilns, which other technologies fail to do.

The MP618 ash beneficiation technology can be delivered as a portable or stationary system depending on client requirements. Charah Solutions' recently completed unit operating in Louisiana processes utility generated ash and can be used to test site-specific fly ash, allowing for a complete analysis of material both pre and post processing.

MP618 technology enhances Charah Solutions' MultiSource materials network, which includes nearly 40 nationwide locations with international sourcing and distribution. This improves our ability to provide a continuous and reliable supply of supplementary cementitious materials (SCMs) for ready-mix concrete producers and other customers.

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INTRODUCTION:

The benefits of using coal combustion products (CCPs), especially fly ash, in the production of concrete products and portland cement manufacturing are well documented. Concrete products manufactured with fly ash are less permeable, last longer, are stronger and more durable, and are easier to handle and finish. Moreover, using fly ash is an environmentally-friendly solution due to the ash being recycled instead of disposed. This approach saves on the use of virgin raw materials typical to concrete production and has a lower overall carbon footprint.

With these benefits, it is easy to see why the power and concrete industries have worked together over the years to increase the beneficial use of coal fly ash. Local, state, and federal government agencies have likewise supported this movement and the results have been rewarding. In 2017, approximately 64% of the CCPs generated at coal fired power stations was recycled for beneficial use, with the majority being used for concrete products and portland cement manufacturing.

Fly ash is used in concrete products and portland cement manufacturing if the CCP composition meets certain requirements. For example, the fly ash must have a minimum concentration of iron, alumina, and silica. Other important constituents include unburned carbon or LOI (loss on ignition), ammonia, sulfur, chlorides, and mercury. ASTM Specification 618 sets the guidelines for ash composition to be used in concrete products (see Table 1).

Table 1: ASTM 618 – Chemical Requirements

	Class		
	N	F	C
SiO2 + Al2O3 + Fe2O3, Min, %	70.0	70.0	50.0
Sulfur Trioxide, Max, %	4.0	5.0	5.0
Moisture Content, Max, %	3.0	3.0	3.0
Loss on Ignition (LOI), Max, %	10.0	6.0	6.0

High moisture, ammonia, and/or carbon content represent the most common obstacles for using fly ash in concrete products. Although not specifically addressed in the ASTM specification, ash with high ammonia content is not used in concrete because of worker safety concerns (i.e. odor). The presence of carbon in the fly ash inhibits the use of chemical admixtures as well as worsening the aesthetics (i.e. color). High moisture ash can negatively affect the concrete mix design and lead to material handling problems.

For portland cement manufacturing, these same constituents are important, and mercury becomes another consideration. Mercury content represents a challenge due to the EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. The mercury content of the fly ash, in some instances, needs to be quite low, typically less than 200 ppb. Although fly ash is generally more valuable if it meets ASTM requirements for inclusion in ready mixed concrete, its use as a raw material in portland cement manufacturing has become commonplace and an important raw material to the industry.

In response to these needs, Charah Solutions has developed a technology that reduces LOI, ammonia, mercury, and moisture content of fly ash, making it reliable and consistent for use in concrete products and portland cement manufacturing. The patented MP618 Multi-Process fly ash thermal beneficiation technology is unique as it addresses multiple constituents within a single process and has no waste streams. It reduces fly ash loss on ignition to concrete standards without changing its chemical structure or destroying its physical characteristics. The technology simultaneously reduces the ammonia concentration, mercury levels, and moisture content of the fly ash too.

This technology can greatly benefit utilities by turning otherwise non-specification fly ash into a marketable product. The benefits of recycling the fly ash are easy to see. The utility avoids the expense of handling and placing the fly ash into a landfill along with the associated "air space" expense for landfill maintenance, and recycling the fly ash helps the utility act as an environmental steward focused on green initiatives.

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TECHNOLOGY / DESIGN:

The MP618 system can be installed to be fully independent from power plant operation, or it can be integrated into the power plant's overall operating plan. Also, the system can be designed to process both fresh production ash or material reclaimed from a landfill or pond. The system can therefore be installed within the active plant area or off-site at the remote landfill or pond site. The modular design consists of four main unit operations or subsystems: feed preparation, thermal desorption, exhaust air treatment, and ash cooling.

Feed preparation for dry, fresh production ash from the power plant is quite simple. It will be comprised of a feed storage silo, holding material from the ash collection system at the utility and feeders to move the material from the silo to the inlet of the thermal desorber. Material may be transported to the thermal desorber with weight belt feeders, air slides, rotary airlock valves, screw feeders or a combination thereof. The exact design of the feed system depends on customer specifications and site-specific requirements.

Processing reclaimed landfill or ponded ash requires an additional feed ash preparation system. Reclaimed fly ash that comes from a landfill and/or pond generally has a higher moisture content and could be coarser than fresh production ash. In this case, the ash can be screened or milled and dried prior to feeding into the thermal desorber.

The dry fly ash from the feed silo is then metered into the thermal desorber chamber where it is exposed to indirect heat. As the material moves along the desorber, the unburned carbon is burned, while ammonia and other volatile components in the fly ash are liberated and swept away by the exhaust air stream. Gravity and small internal lifter bars convey the fly ash along the length of the desorber. The processed ash exits the desorber and gets transported by screw feeder to the ash cooler, while the exhaust air gets routed to the high temperature baghouse where a small amount of entrained particulate is captured. The collected particulate is transferred to the final product storage silo, and the dust-free air stream is routed to the environmental control technology (ECT).

The ECT is a modified particulate scrubber with a recirculating stream of dilute reagent. The exhaust air stream from the baghouse flows through the ECT chamber while the reagent flows counter-current of the gas stream through the chamber. The ECT

internals include impingement plates to promote intimate contact between the exhaust air and reagent. The ECT forces the heavy metals being carried by the exhaust air stream to chemically react with and bond to the reagent. The result of this reaction is a solid particle that is isolated and collected. The particulate is then collected in the ECT holding tank, while the unspent reagent solution is filtered and re-introduced to the ECT. The chemical reaction occurs on a molar basis, which allows the reagent solution to be continuously recycled back through the ECT until it has been fully reacted.

The residue is then blended into the finished product from the plant. Instead of generating thousands of tons of low concentration sorbents which must be landfilled, the MP618 process generates a small amount of concentrated residue that is both non-toxic and non-leachable. Generally, this process generates less than 30 tons per year of residue for 200,000 tons of fly ash processed.

The cooling system design can take many forms and is customized to the plant. The system can use air cooled heat exchangers, chillers, cooling towers with a closed loop water circuit, etc. The ash cooler simply reduces the temperature of the ash exiting the thermal desorber so that it can be safely handled and stored. The ash will be transported from the ash cooler to final product storage.

The throughput of the system is dependent on the fly ash characteristics. As one might expect, materials with higher LOI content generally require longer treatment times than lower LOI ash. The operating temperature of the system also depends on the ash constituents. The operating speed of the desorber, treatment temperature, and exhaust air flow rate are optimized for each unit during start-up and commissioning. These parameters are then monitored during operation, and adjusted if necessary, to ensure a consistent product stream that meets the project's specification requirements.

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TEST RESULTS:

The test results from the Louisiana based plant have showed consistent LOI reduction over a wide range of fly ash inputs. For all testing, a grab sample of material is taken at the inlet of the thermal desorber and at the ash cooler inlet. Each sample is tested at the on-site laboratory for moisture and LOI content. The moisture is determined via a calibrated moisture analyzer. The LOI content is determined by comparing the weights prior to and after placing the ash sample into a muffle furnace for one hour. Periodically, a second sample is gathered and sent to an independent, off-site testing laboratory for analysis. This approach provides confirmation of the on-site measurements and confirms the accuracy of testing equipment.

The removal of ammonia is equally impressive. Test results indicate that the system can remove over 90% of the ammonia bound in the fly ash. The system reduced ammonia from as high as 435 ppm to less than 50 ppm in fly ash from a unit burning Illinois basin coal. Another test showed 91% removal of ammonia with the concentration reduced from 431 ppm to 37 ppm. Due to the increased alkalinity of fly ash from a plant firing PRB coal, it is expected the system can achieve even lower ammonia levels when processing PRB coal ash. Future tests are planned in July 2019 to confirm this hypothesis.

Date	Raw LOI (%)	Processed LOI (%)	% Reduction
Sept. 2018	4.3	0.61	86%
Sept. 2018	4.52	0.57	87%
Oct. 2018	9.5	1.45	85%
Oct. 2018	9.5	0.6	94%
Oct. 2018	5.3	0.5	91%
Oct. 2018	4.4	1.07	76%
Nov. 2018	5.3	1.5	72%
Nov. 2018	4.0	0.6	89%
Nov. 2018	6.0	1.7	58%
Jan. 2019	6.0	0.5	92%
Jan. 2019	6.0	0.5	92%
Jan. 2019	5.4	0.81	85%

Numerous tests have been conducted on the system to measure performance regarding the mercury concentrations in the fly ash as well as the exhaust air stream. The mercury levels in the fly ash were determined from grab samples at the system inlet and outlet by an independent laboratory using either Method EPA 7471 or ASTM D6722. Mercury in the exhaust air stream was measured before and after the wet scrubber by a third-party contractor using a combination of handheld Jerome mercury analyzers, total mercury sorbent traps, and speciated mercury sorbent traps.

The results indicate good, consistent removal of mercury from the fly ash with all ash tested having a final concentration below 100 ppb. In fact, the system has been shown to produce an ash with very low mercury concentration regardless of the raw mercury level prior to processing. The system has been tested with ash having over 40,000 ppb of mercury, and the processed material still contained less than 100 ppb of mercury. However, most ash tested had inlet mercury concentrations between 300 and 600 ppb.

The system does an equally good job of capturing the mercury from the exhaust air stream. Mercury removal as high as 99% has been observed, and we have not seen mercury removal below 90% in any tests conducted so far. During our most recent demonstration testing, the mercury emissions averaged 44 ppb over the entire test period. Perhaps most importantly, the MP618 process produces a concentrated, low volume stream of heavy metal residue which is in particulate form.

	MCS RESIDUE		
	LIQUID	SOLID	UNIT
Total Mercury	ND	2360	mg/kg
Metals SM3120 B			
Arsenic	0.043	147	mg/kg
Barium	0.054	141	mg/kg
Cadmium	ND	49	mg/kg
Chromium	ND	166	mg/kg
Lead	ND	16	mg/kg
Selenium	ND	ND	mg/kg
Silver	ND	514	mg/kg

RAW FEED

PROCESSED

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CONCLUSION:

The MP618 system is an economical, innovative method to reduce carbon (LOI), ammonia, and mercury levels in coal combustion fly ash. The technology can be used to beneficiate fresh production fly ash as well as reclaimed ash from existing impoundments and landfills. The process can reduce LOI concentrations by as much as 95% and consistently achieve LOI levels below 1.0% for most ash. In addition, the technology has been proven to remove 90% of the ammonia in the ash.

This environmentally-friendly process captures the vaporized mercury (elemental and ionic forms) and other heavy metals from the ash and forms a non-leachable, non-hazardous residue. The very low volume residue stream is recycled back to the process to eliminate any waste streams. The system consistently reduces the mercury concentration of the fly ash to less than 100 ppb while capturing as much as 99% of the volatized mercury from the exhaust air stream.

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