2022

EMISSIONS CONTROL

PROJECT PORTFOLIO

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

DISCLAIMER

This project was funded by the United States Department of Energy, National Energy Technology Laboratory, in part, through a site support contract.

CONTENTS

INTRODUCTION

The Emissions Control Program supports the DOE Office of Fossil Energy and Carbon Management's mission of minimizing the environmental impacts of fossil fuels while working toward net-zero emissions by addressing critical operational and environmental issues impacting the U.S. coal-based power generation sector. Specifically:

Advanced Concepts and Technologies to Increase the Beneficial Use of Coal Combustion Residuals

Research and development (R&D) in this area will advance technology applicable to increasing the beneficial utilization of coal combustion residuals (CCR) via:

- Innovative technology and concepts to increase beneficial utilization: R&D will to be directed at (1) the fraction of coal combustion products that are not currently being recycled or beneficially reused at high levels such as non-gypsum, wet- and dry- flue gas desulfurization materials and bottom ash and/or (2) materials used in current CCR facilities that may be negatively impacted by new CCR regulations.
- Innovations for improved cost and performance of CCR beneficiation/upgrading technologies: R&D to focus on improvements in the performance and cost of beneficiation/upgrading of technology associated with high-volume reuse materials (i.e., fly ash and synthetic gypsum).
- Innovative technology and processes for utilizing CCR in storage impoundments: Advanced cost-effective approaches for removing, upgrading, and beneficially recycling CCR from active and inactive storage impoundments are sought.

Advanced Concepts and Technologies for Managing Inactive and Legacy CCR Impoundments

R&D in this area will advance technologies applicable to improving the management or closure of active and inactive CCR disposal sites. The approaches being pursued are:

- Innovative technologies, concepts, and processes for managing and/or closing-in-place inactive or legacy storage impoundments: Approaches that provide a cost-efficient and environmentally sound alternative to the physical removal of the material are of interest. R&D is sought for innovative technologies, concepts, and processes to stabilize, neutralize, and/or encapsulate trace metals and other contaminants in unlined or inadequately lined inactive or legacy disposal sites.
- Innovative technologies, concepts, and processes for CCR impoundment leachates: innovative concepts are sought that will treat leachates and related discharges from both active and inactive (legacy) unlined or inadequately lined CCR impoundments and ponds with a particular focus on arsenic and selenium. These treatment technologies should be relatively small and modular in design with the assumption that further development could allow them to be mobilized.

Technologies developed under the Emissions Control program will responsibly divert coal CCR towards beneficial reuse, improve the operation and management of existing and legacy CCR impoundments, and reduce the volume of CCR needed to be disposed of in impoundments while protecting the environment and the health and safety of the public.

ADVANCED CONCEPTS AND TECHNOLOGIES TO INCREASE THE BENEFICIAL USE OF COAL COMBUSTION RESIDUALS

Facilitating Implementation of High-Volume Fly Ash use in Precast Concrete Construction to Increase Beneficial Utilization

Performer	**Illinois Institute of Technology**
Award Number	FE0031931
Project Duration	10/01/2020 – 09/30/2022
Total Project Value	$ 1,244,344
Focus Area	Innovative technology and concepts to increase beneficial utilization

The main goal of this project is to increase the beneficial use of fly ash as a supplementary cementitious material for precast concrete applications. The major focus of this project is to develop balanced concrete mix design strategies which collectively satisfy the following objectives: (1) increase fly ash beneficial use by at least 15% in the precast concrete industry, (2) maintain or exceed stringent structural property requirements (e.g., compressive strength at initial prestress, modulus of rupture, etc.), (3) exhibit little or no additional cost relative to conventional mixtures, and (4) mitigate detrimental environmental consequences inadvertently caused by increased beneficial use.

Anticipated outcomes of this project include significantly increased beneficial use of fly ash in the concrete industry via the precast construction sector, revised design guidelines and code provisions for sustainability requirements for concrete mix designs, diversion of large quantities of fly ash from landfills or impoundments, and establishing a framework for incorporating lesser-used coal combustion residual materials (e.g., fly ash which does not meet applicable specification requirements) in concrete construction practices.

Development of a high-volume fly ash implementation framework for precast concrete construction will encompass (a) participation from a coal-fueled power generation facility and fly ash distributor, (b) cutting-edge concrete materials science research, and (c) fabrication and experimental testing of (d) full-scale precast components.

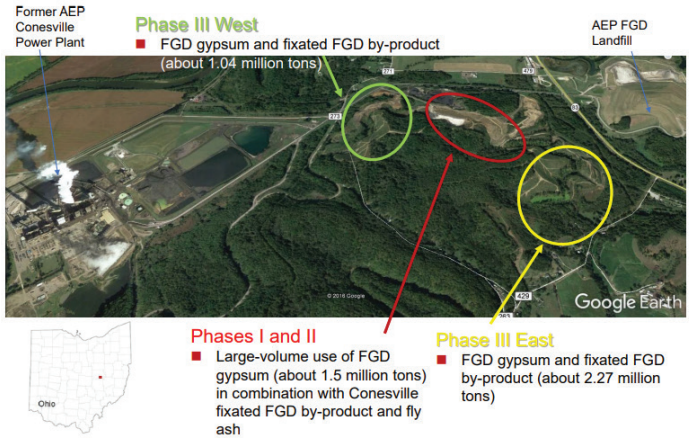
Beneficial Use of Harvested Ponded Fly Ash and Landfilled FGD Materials for High-Volume Surface Mine Reclamation

Performer	**Ohio State University**
Award Number	FE0032038
Project Duration	07/06/2021 – 07/05/2023
Total Project Value	$ 1,273,996
Focus Area	Innovative technology and processes for utilizing CCRs in storage impoundments

The focus of this project will be on the viability of beneficial use of harvested coal combustible residuals (CCRs), especially ponded fly ash and landfilled flue gas desulfurization (FGD) by-products. The project will take place at three sites represented by circles in the adjacent graphic. The proposed project is designed to demonstrate laboratory- as well as bench-scale testing and construction methods that can be applied to a wide variety of ash ponds, closed FGD landfills, and abandoned coal mine sites in the United States. The major tasks for this project are:

1. Geotechnical and environmental testing and evaluation using an existing bench-scale facility of harvested ponded fly ash and landfilled FGD material at the former Conesville, Ohio power plant. Successful completion of the lab- and bench-scale testing will lead to Task 2 - Conesville Full-Scale Demonstration.
2. About 2 million tons of harvested CCR materials from an inactive fly ash pond and an adjacent old FGD landfill will be used to fully reclaim a nearby partially-abandoned surface coal mine. Site monitoring will be carried out during the project.
3. Numerical models leveraging the rich set of data collected from the Conesville site will be used to analyze risks for high-volume surface mine reclamation with harvested CCRs. Transport simulators and geochemical reaction models will be integrated, calibrated, and validated. Sensitivity analysis of the temporal evolution and significance of the factors involved in the process will be performed to determine significant risk factors and drivers.

The project could result in reduced by-product liability and disposal costs for coal-fired utilities in a manner that is economically viable and beneficial to the environment, the public's health and safety, and the power-generating companies. Also, the results of this project could provide owners, design engineers, and regulatory agencies with specific information about the technical feasibility and probable cost of using these methods for remediation and reclamation of abandoned coal mine sites across the United States, especially in eastern and midwestern coal mining regions.



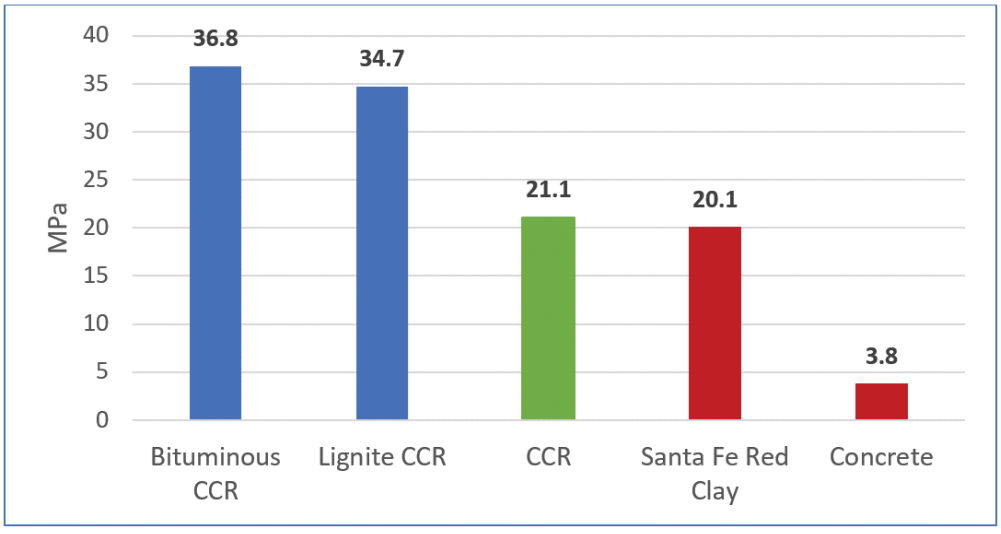
Locations of Conesville Five Points Reclamation Projects.

High Strength, Encapsulated, Commercially Useful Components and Particles Made from Coal Combustion Residuals

Performer	**Semplastics EHC, LLC**
Award Number	FE0031932
Project Duration	10/01/2020 – 09/30/2022
Total Project Value	$ 1,407,585
Focus Area	Innovations for improved cost and performance of CCR beneficiation/upgrading technologies

Semplastics aims to demonstrate the effectiveness of their Coal Combustion Residuals (CCR) encapsulation technology. Samples of the selected CCR will be encapsulated and undergo leach testing to show reduction of toxic element leaching by more than 80%. The project team will mold test plates from CCR and a number of inorganic resins, which will be cut into test specimens for microstructural, mechanical, and physical property analysis. The process developed in making the test plates will be used for scale-up to make bulk demonstration parts. The team will optimize the scaled-up process to produce large-scale support columns (approximately 9" diameter). The team will develop two predictive models—one for encapsulated CCR in high-CCR-loaded bulk parts, and one for encapsulated CCR as filler in polypropylene. By the end of the project, the team plans to demonstrate that encapsulated CCR improves the strength and modulus of polypropylene by 30-50% and can be used in structural components to provide a strength five to ten times that of concrete.

If successful, it will result in a feasible, high-volume method of mitigating the effects of CCR leaching into the environment and enable the use of virtually all CCR including previously non-viable CCR for commercial applications. This work will also provide at least two routes to utilize large volumes of CCR in materials that are commercially viable with high-volume markets. Expected beneficiaries of this work include owners of current and formerly operational coal-based power plants, who will be able to leverage a new use for their current and past waste products; the construction industry, who will have access to new high-strength, fast-hardening support structures, and the plastics industry, who will gain new high-performance plastics at polypropylene prices.



Initial results show CCR-based materials have up to 10x higher flexure strength than concrete.

Surface Modified Fly Ash For Value Added Products (SuMo Fly Ash)

Performer	**University of Illinois**
Award Number	FE0032039
Project Duration	08/01/2021 – 07/31/2023
Total Project Value	$ 1,230,015
Focus Area	Innovations for improved cost and performance of CCR beneficiation/upgrading technologies

The primary objective of this project is to develop a technology to encapsulate coal fly ash particles in sulfurized vegetable oil to enhance its physical and mechanical properties by inherently reducing its metal leaching potential, for use as novel fillers in multi- polymeric matrices such as plastics and elastomers. It will be demonstrated that these encapsulated fly ash particles will improve functional properties of plastics and elastomers and have comparable or improved environmental release of constituents of potential concern (COPC) compared to non-CCR (coal combustible residuals) products, thereby meeting EPA evaluation criteria for CCR encapsulated beneficial use.

If successful, surface-modified (SuMo) fly ash will overcome some of the inherent barriers to fly ash utilization, such as regional and seasonal imbalances in supply and demand and transportation and beneficiation costs. Additionally, sulfurized vegetable oil-coated fly ash particles could provide both economic and functional benefits as a polymer filler, as they have improved mechanical properties and lower cost in comparison to traditional organic filler.

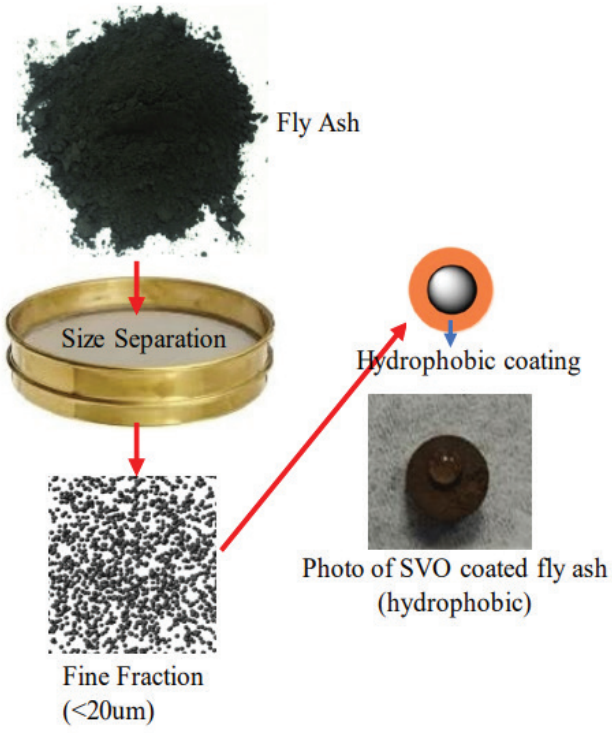


Diagram of the method used to process coal fly ash into coated fly-ash particles.

ADVANCED CONCEPTS AND TECHNOLOGIES FOR MANAGING INACTIVE AND LEGACY CCR IMPOUNDMENTS

Phytostabilization as a Tool for Managing Risk of Selenium and Arsenic Exposure from Coal Ash

Performer	**Engineer Research and Development Center (ERDC)**
Focus Area	Innovative technology, concepts, and processes for managing, stabilizing, monitoring, and/or closing-in-place inactive or legacy storage impoundments

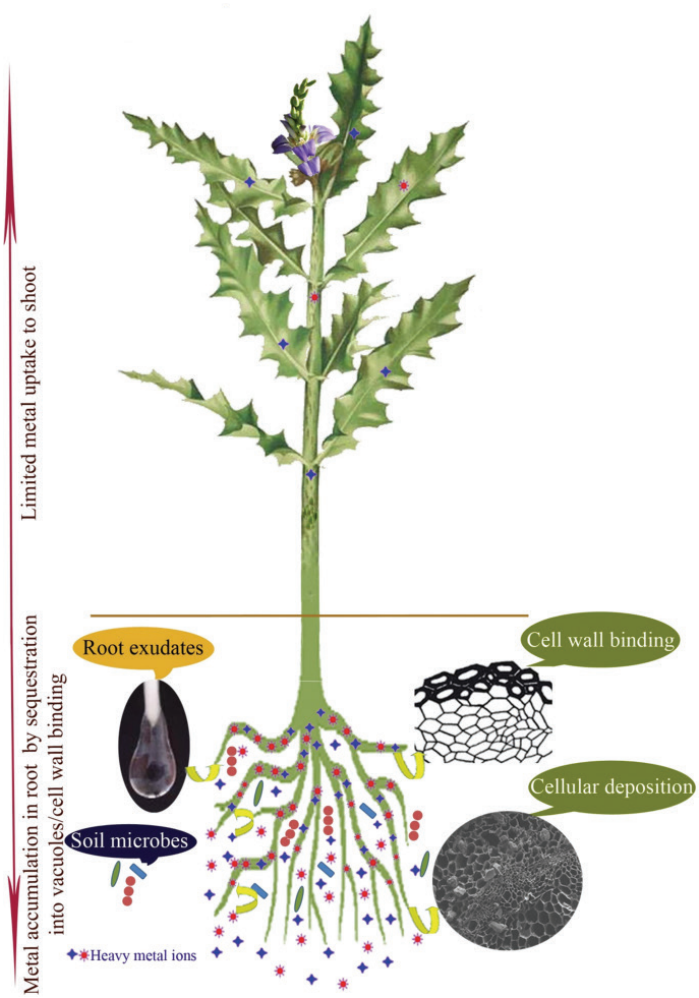
The U.S. Army's Engineer Research and Development Center (ERDC) is examining the effects of phytostabilization on the soil mobility of selenium and arsenic compounds from coal ash. Various plant genera and species that can target these compounds are under examination as sentinels to indicate elevated risk potential of arsenic and selenium near coal ash impoundments. The results of this study will be used to inform FECM's Risk Management Framework currently under development.

As described above, the results of this study can be adapted for FECM's Risk Management Framework, which will inform future coal combustion residual (CCR) risk management studies and projects.

The plants identified as a part of this study can also be used for coal ash stabilization work in the future, resulting in a less invasive, lower cost option for soil stabilization and site monitoring.

Finally, the reduced mobility of contaminants lowers the risk that they will find their way into groundwater sources or further entry into the food chain.

- ERDC has performed a comprehensive literature review of phytoremediation studies involving arsenic and selenium.
- Criteria for selecting various plant genera has been identified.
- Further literature studies are needed to refine the selection process, specifically as the plants relate to site conditions like climate, level of contamination, chemical properties, etc.



Phytostabilization mechanism.

Risk Management Framework for Coal Combustion Residue Impoundments

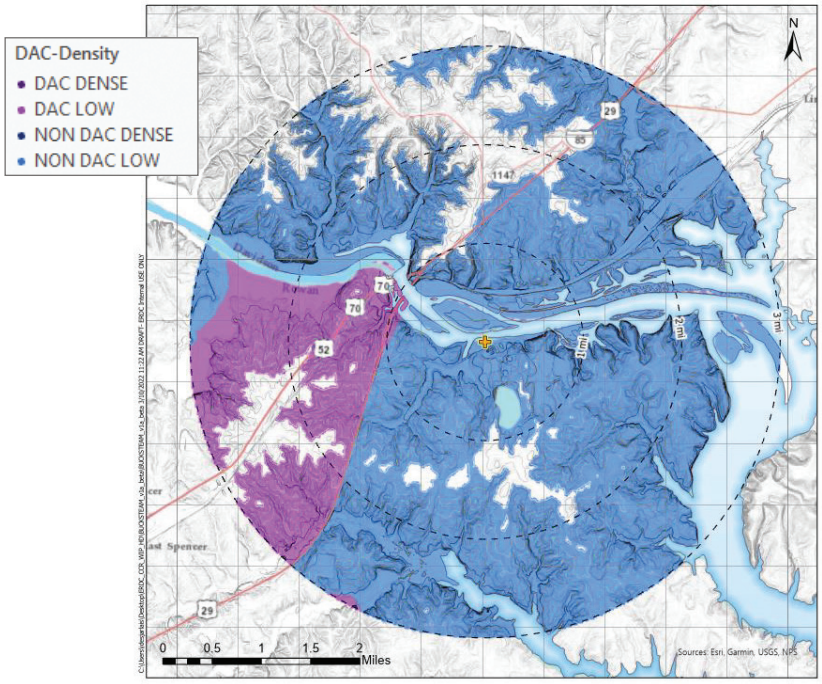
Performer	**Engineer Research and Development Center (ERDC)**
Focus Area	Innovative technology, concepts, and processes for managing, stabilizing, monitoring, and/or closing-in-place inactive or legacy storage impoundments

The U.S. Army's Engineer Research and Development Center (ERDC) is working with FECM to develop a risk management framework for coal combustion residuals (CCRs) at ash impoundment sites. The framework seeks to address whether it is worth it (or not) to generate by-products from coal ash at target sites as well as determine which sites are most suitable for by-product generation. The framework utilizes a systematic process of risk evaluation in order to inform assessors of the nature of risks present using available knowledge.

The survey and resulting framework will answer key value propositions of by-product generation at specific impoundments, leading to increased revenues, which can offset or overcome the cost of regulatory compliance in addition to reducing the impact of new CCRs entering impoundments each year (currently ⅓ of all CCR produced in the U.S. are received by surface impoundments).

Finally, there is a growing interest in discovering new materials, and the successful adoption of a by-product generation scheme can accelerate the development of these new materials in the emerging market.

- ERDC has performed 6 separate CCR impoundment case studies that represent a range of characteristics.
- For each study, criteria such as land use and elevation, economic return periods, safety risk factors, and surrounding community demographics were examined and quantified.
- Each metric was converted into an aggregate score and plotted in the form of a polygon chart (right) to compare each site's risk potential



Population density and disadvantaged community (DAC) status surrounding the impoundment.

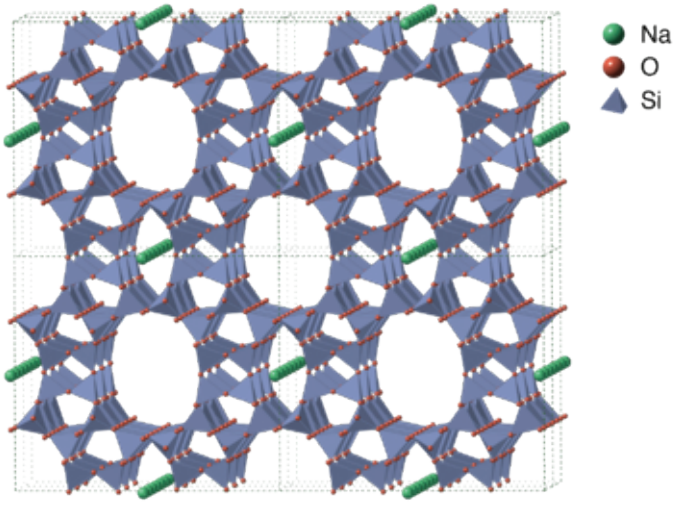
Machine Learning Aided Development of Sorbents to Treat Leachates (From Ash Impoundments)

Performer	**National Energy Technology Laboratory (NETL)**
Award Number	FWP-1022479
Project Duration	04/01/2021 – 03/31/2023
Total Project Value	$ 300,000
Focus Area	Innovative technology, concepts, and processes for CCR impoundment leachates

Sorbents are widely employed for the clean-up of fluids such as coal-derived flue gas and drinking water and in gas masks, and have over $10 billion in sales annually in the United States. A proof-of-concept artificial intelligence/machine learning (AI/ML) methodology will be developed to design optimal promoted zeolite sorbents for the treatment of ash impoundment leachate. Zeolites can be readily synthesized from materials contained within the coal combustion ash impoundments and can be promoted or cation exchanged to enhance capacity and reactivity.

Benefits of this work would include remediation of domestic ash impoundments, generation of beneficial byproducts from coal combustion residuals, and development of a proof-of-concept AI/MI methodology for rapid design of sorbents tuned to specific ash impoundment and/or landfill requirements.

An additional rationale for development of this methodology is that sorbents are typically developed through laborious, expensive, and time-consuming experiments, often taking years for commercial development. The proposed methodology will promote U.S. leadership in sorbent development, creating domestic jobs and reducing time and effort for the sorbent formulation.



Mordenite (MOR framework).

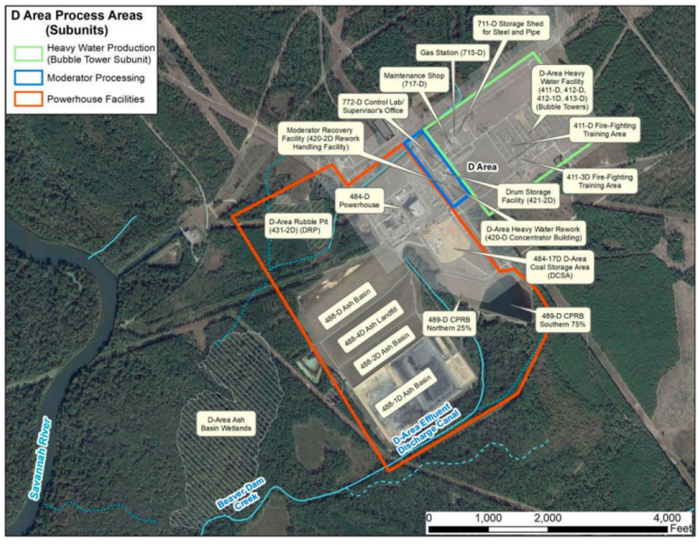
Identification of Master Variables Controlling Contaminant Migration at the SRS D-Area Ash Basins

Performer	**Savannah River National Laboratory**
Focus Area	Innovative technology, concepts, and processes for managing, stabilizing, monitoring, and/or closing-in-place inactive or legacy storage impoundments

Savannah River National Laboratory is adapting an environmental monitoring strategy traditionally used for radioactive compounds from nuclear facilities for coal combustion residual (CCR) storage facility monitoring. The Advanced Long-Term Environmental Monitoring System (ALTEMIS) incorporates advanced monitoring techniques, such as in-situ real-time monitoring for early warning systems, to ensure continued compliance with regulations as well as prevent environmental harm and damage to public health.

The project will utilize data analytics and artificial intelligence/machine learning (AI/ML) techniques to examine and characterize contaminant transport behavior. These studies will help refine the process for coal ash storage facilities, resulting in reduced costs for monitoring systems, and a higher degree of protection of the surrounding environment (such as groundwater and nearby bodies of water).

- The researchers have collected data on over 139 groundwater monitoring wells spanning from the 1980s to present day. The historical data includes geochemical measurements of various harmful compounds in the surrounding soil.
- Aquifer and water table surveys were performed throughout the D-Area coal ash basin.
- Several correlations between specific contaminants and other measurement variables have been quantified.



D-Area ash basins.

Existing groundwater monitoring wells.

ABBREVIATIONS

AI/ML .....artificial intelligence/machine learning

ALTEMIS..... Advanced Long-Term Environmental Monitoring System

CCR .....coal combustible residuals

COPC..... constituents of potential concern

FGD ..... flue gas desulfurization

SuMo ..... surfaced-modified

NOTES

NOTES

NOTES

CONTACTS

David K. Lyons
Technology Manager
Emissions Control

304-285-4379

K.Lyons@netl.doe.gov

Mary Sullivan
Supervisor
Crosscutting Team

412-386-7484

Mary.Sullivan@netl.doe.gov

WEBSITES:

https://netl.doe.gov/carbon-management/carbon-capture

ACKNOWLEDGMENTS

The Emissions Control Portfolio was developed with the support of many individuals. Key roles were played by principal investigators, federal project managers, the technology manager, the supervisor, and National Energy Technology Laboratory site-support contractors.

NATIONAL ENERGY TECHNOLOGY LABORATORY

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Program staff are also located in
Houston, TX and **Anchorage, AK**.

Visit us: **www.NETL.DOE.gov**

@NationalEnergyTechnologyLaboratory

@NETL_DOE

@NETL_DOE

U.S. DEPARTMENT OF ENERGY

July 2022