

# Managing Coal Combustion Residues in Mines

Committee on Mine Placement of Coal Combustion Wastes  
Board on Earth Sciences and Resources  
Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL  
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## Summary

Coal is the world's most abundant fossil fuel and the largest single source of fuel for electricity production in the United States. More than 90 percent of the coal mined in the United States is used by commercial power plants to generate electricity.

A by-product of coal combustion is the formation of coal combustion residues (CCRs), the noncombustible portion of the coal itself and residues from various air pollution control technologies. The amount of CCRs produced annually is currently more than 120 million tons, which is enough to fill about one million railroad coal cars. This amount will likely continue to increase as demand for coal-based energy in the United States grows and as air pollution control technologies for capturing residues are more widely used.

The management of large volumes of CCRs is a challenge, particularly for utilities that must dispose offsite or find secondary uses for this material. CCRs can be recycled for use into engineering applications or products such as cement or wallboard, which relaxes disposal needs. The remainder must be disposed in landfills, surface impoundments, or mines. Each method for disposing of CCRs has advantages and disadvantages in terms of cost and potential impacts. Placement of CCRs in mines for mine reclamation, the focus of this study, is not currently a major national practice. However, the use of CCR in mine reclamation has been increasing (ACAA, 1995; ACAA, 2005c; PADEP, 2004). *The committee concluded that putting CCRs in coal mines as part of the reclamation process is a viable management option as long as (1) CCR placement is properly planned and is carried out in a manner that avoids significant adverse environmental and health impacts and (2) the regulatory process for issuing permits includes clear provisions for public involvement.* The main advantages of CCR mine placement are (1) it can assist in meeting reclamation goals (such as remediation of abandoned mine lands), and (2) it avoids the need, relative to landfills and impoundments, to disrupt undisturbed sites. However, the placement of CCRs in coal mines is a multidimensional issue that involves consideration of potential human health and environmental impacts, as well as a comparison to the economic, health, and environmental impacts from other uses or disposal options.

Concerns about the potential public health and environmental risks associated with using CCRs for reclamation in active and abandoned coal mines led Congress to direct the Environmental Protection Agency (EPA) to commission an independent study to examine this topic (Sidebar S.1). As a result, the National Research Council established the Committee on Mine Placement of Coal Combustion Wastes study to address issues outlined in the statement of task.

**SIDEBAR S.1**  
**Statement of Task**

In response to a request from Congress, the National Research Council conducted a study that examined the health, safety, and environmental risks associated with using coal combustion wastes (CCW)' for reclamation in active and abandoned coal mines. The study looked at the placement in abandoned and active, surface and underground coal mines in all major coal basins. The study considered coal mines receiving large quantities of coal combustion wastes. The committee focused its efforts on coal combustion wastes from utility power plants and independent power producers, rather than small business, industries, and institutions. A profile of the utility industry was taken into consideration in designing the study to focus on the sources producing the greatest quantities of coal combustion wastes.

Specifically, the committee addressed the following points:

1. The adequacy of data collection from surface water and ground water monitoring points established at CCW sites in mines,
2. The impacts of aquatic life in streams draining CCW placement areas and the wetlands, lakes, and rivers receiving this drainage.
3. The responses of mine operators and regulators to adverse or unintended impacts such as the contamination of ground water and pollution of surface waters.
4. Whether CCWs and the mines they are being put in are adequately characterized for such placement to ensure that monitoring programs are effective and ground water and surface waters are not degraded.
5. Whether there are clear performances standards set and regularly assessed for projects that use CCW for "beneficial purposes" in mines,
6. The status of isolation requirements and whether they are needed.
7. The adequacy of monitoring programs including:
  - a. The status of long-term monitoring and the need for this monitoring after CCW is placed in abandoned mines and active mines when placement is completed and bonds released;
  - b. Whether monitoring is occurring from enough locations;
  - c. Whether monitoring occurs for relevant constituents in CCW as determined by characterization of the CCW; and
  - d. Whether there are clear, enforceable corrective actions standards regularly required in the monitoring.
8. The ability of mines receiving large amounts of CCW to achieve economically-productive post mine land uses,
9. The need for upgraded bonding or other mechanisms to assure that adequate resources area available for adequate periods to perform monitoring and address impacts after CCW placement or disposal operations arc completed in coal mines.
10. The provisions for public involvement in these questions at the permitting and policy-making levels and any results of that involvement.
11. Evaluation of the risks associated with contamination of water supplies and the environment from the disposal or placement of coal combustion wastes in coal mines in the context of the requirements for protection of those resources by the Resource Conservation and Recovery Act (RCRA) and the Surface Mining Control and Reclamation Act (SMCRA).

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' Although the term "coal combustion wastes" (CCW) was used in the statement of task, after much discussion the committee chose to use the torn "coal combustion residue" (CCR) for the purpose of this report. This term was chosen to avoid implying that these materials are destined for particular fates.

## PO'TENTIAL IMPACTS FROM COAL COMBUSTION RESIDUE PLACEMENT IN MINES

Coal combustion residues may be effective in neutralizing acid mine drainage and therefore reducing the overall transport of contaminants from acid-generating mine sites. However, CCRs often contain a mixture of metals and other constituents in sufficient quantities that they may pose public health and environmental concerns if improperly managed. In a mine setting, subsurface water flow is the primary mechanism for transporting contaminants from CCRs to potential human and ecological receptors. Risks to human health and ecosystems may occur when CCR-derived contaminants enter drinking water supplies, surface water bodies, or biota. Impacts on downgradient water quality will depend on the concentration of the contaminant, the flow rate and volume of contaminated water entering the flow system, and the ability of the aquifer or receiving water body to dilute or attenuate the contamination. The concentration, volume, and flow rate of contaminated water, in turn, depend on the leachable mass of toxic constituents in the CCR, the emplacement design, and the local hydrogeologic setting.

*Of the three methods currently available for disposal of CCRs (surface impoundments, landfilling, and minefilling), comparatively little is known about the potential for ininefilling to degrade the quality of groundwater and/or surface waters particularly over longer time periods. Additionally, there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessments difficult.* The committee was presented with numerous testimonies in which public citizens, industry, and state regulatory agencies disagreed about the extent of the degradation of water quality associated with CCR placement in mines. The EPA has not identified any cases in which exceedances of water quality standards could be attributed directly to CCR mine placement. However, the committee's review of literature and damage cases recognized by EPA supports the EPA's concerns about proper management of CCRs.

Thus, *the committee concludes that the presence of high contaminant levels in many CCR leachates may create human health and ecological concerns at or near some mine sites over the long term.* The two most common CCR disposal options, surface impoundments and landfills, provide insights into the types of issues that can emerge when the soluble constituents of CCRs are not contained within the waste management system. Although disposal conditions may differ substantially from mine settings, landfills and surface impoundments are useful for understanding the specific conditions under *which CCRs can* potentially impact humans and ecosystems. The EPA *has* identified numerous cases of water contamination related to CCR landfills and surface impoundments that, in many cases, has caused considerable environmental damage. In some landfill settings, groundwater has been degraded to the point that drinking water standards were exceeded off site. In other landfills and surface impoundments, contamination of surface waters has resulted in considerable environmental damage; in the most extreme cases, multiple species have experienced local extinctions. Such cases are instructive because these impacts can be clearly related to CCR disposal, and they help guide the selection of mining environments for CCR placement that are most protective of human and ecological health.

## PLANNING FOR CCR USE

A variety of steps are involved in planning for and managing the use of *CCRs as* minefill. The report discusses practices that could reduce the potential impacts associated with the use of CCRs in reclamation.

### CCR Disposal and Use Options

A variety of alternative uses and disposal options are available for CCR, including its secondary use for the manufacture of products or its disposal in landfills, surface impoundments, and mines. The chemical and physical characteristics of a particular CCR stream, coupled with consideration of issues such as the demands for alternate uses, costs and locations of disposal options, and the local regulatory environment, are key to determining the best option for CCRs. In its 2000 regulatory determination, EPA concluded that CCRs used for beneficial purposes other than minefilling should remain exempt from regulation as a hazardous waste under RCRA. They further determined that in many uses, *CCRs* would be bound or encapsulated in construction materials and therefore were not likely to present a significant risk to human health or the environment. Although the focus of this study is the use of CCRs as minefill, the loss of valuable residues to the waste stream may represent missed opportunities for waste reduction and environmentally sound management. Therefore, **the committee recommends that secondary uses of CCRs that pose minimal risks to human health and the environment be strongly encouraged.**

Many CCRs are not suitable for secondary uses and must be disposed in landfills, impoundments, or mines. In cases where placement in a mine site during reclamation is determined to be a viable option, an integrated process of CCR characterization, site characterization, management of placement activities, and post-placement monitoring is required. The volume of CCR material to be used and the relative risk that emerges from the site and material characterization should help determine the level of additional effort that will be required to manage and monitor the mine site.

While recognizing the potential risk of negative environmental impacts associated with CCRs minefilling, it has been shown that, in *some cases*, benefits can accrue and should be considered in the permitting process. Some states have designated the use of CCR in the reclamation of coal mines as a beneficial use. The evaluation of risks and benefits is always a complicated analysis, confounded by determining who may bear the risks and who may accrue the benefits. The process for permitting beneficial use varies among the states, and in many states, the designation of beneficial use may limit the regulation or oversight of CCR placement. *With regard to CCR placement in minefills, the committee concludes that while potential advantages should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use.*

## Characterizing a Mine Site Disposal Option

Characterization of the CCR material and the mine placement site is essential to engineering design, permitting decisions, reclamation management, and the development of monitoring programs. Successful predictions of CCR behavior in the mine environment require a thorough understanding of the complex physical and biogeochemical processes, associated primarily with subsurface flow, that control the release and transport of CCR-derived constituents. The mobility of CCR-derived constituents varies widely in the mine environment depending on the physical and chemical characteristics of the CCRs and geologic materials, and the pH, oxidation-reduction potential, and chemical composition of the water encountered at a mine site. All of these factors must be considered in characterizing the mine site disposal option.

### CCR Characterization

The characterization of CCRs involves analyses of bulk chemical and physical properties, including trace element leaching potential, cementitious properties, and any other ash characteristics (i.e., permeability upon compaction) that might impact their behavior in the mine setting. **To contribute to evaluation of the risk of placing CCRs at mine sites, the committee recommends that CCRs be characterized prior to significant mine placement and, with each *new source of CCRs*, CCR characterization should continue periodically throughout the mine placement process to assess any changes in CCR composition and behavior.**

Leaching tests are commonly applied to assess the potential release of trace elements from CCRs. The limitations of single-point batch tests are well recognized, although they remain in widespread use and have a major role in the regulation of CCR mine placement in many states. Alternative leaching *methods* are being developed to address these limitations; but, until they are more thoroughly evaluated, the committee suggests some simple improvements to current leaching protocols. In particular, the CCR characterization methods used should provide contaminant leaching information for the range of geochemical conditions that will occur at the CCR placement site and in the surrounding area, both during and after placement. Samples that exceed pre-determined leaching criteria should be rejected for mine placement, although samples that meet the criteria may still need additional evaluation depending on the potential risks of CCR placement determined from the site characterization.

### Site Characterization

Site characterization is a dynamic process of developing and continually refining a site conceptual model that captures the relevant aspects affecting the behavior of CCRs in the mine environment. When integrated with CCR characterization data, site characterization provides the information necessary to locate the best places within the mine for placing CCRs, to design the CCR emplacement, and to develop the monitoring plans. Current site characterization requirements under the Surface Mining Control and Reclamation Act (SMCRA) focus on assessing the potential impacts of coal mining and reclamation but do not specifically address the impacts of CCR placement.

**The committee recommends that comprehensive site characterization specific to CCR placement be conducted at all mine sites prior to substantial placement of CCRs.** Site characterization should encompass a full description of the hydrogeological setting, including aquifer locations and groundwater flow patterns, surface water drainage and flow, and soil and overburden characterization. Site characterization should define the mine site hydrogeology and geochemistry in both undisturbed areas and reclaimed mining areas and should also consider local factors, such as surrounding land use, proximity to human and ecological receptors, and designated future land use. In addition, site characterization should assess the potential for human exposure to drinking water impacts that might occur related to CCR placement.

### **CCR Use in Reclamation Operations**

The site and material characterization data, including the description of the hydrogeological and biogeochemical setting of the mine and the bulk chemical and physical properties of the CCRs, should be integrated to develop a plan for CCR placement. The engineering design should consider the mass of material to be placed as well as placement locations within the mine site. This plan should be informed by the risks associated with the site and the CCR material present.

#### **Reclamation**

The use of CCR for minefill should be viewed in the context of general reclamation management activities. The primary reclamation operations most readily impacted by CCR placement are backfilling and grading, topsoil replacement, and revegetation. The disposal of CCRs in coal mines occurs under highly variable conditions, ranging from small quantities to massive minefills, from arid to wet regions, from remote to semiurban locations, from surface to underground mines, and from active to abandoned mines. Thus, **the committee endorses the concept of site-specific management plans, including site-specific performance standards.** A flexible approach to managing CCRs in mine sites has advantages since it can embrace the unique characteristics of the CCRs, the total mass of CCRs, and the environment into which they are placed. However, the need to incorporate site-specific factors should not be a basis for adopting management plans that lack rigor. Such plans should be developed in compliance with enforceable standards for using CCRs in minefilling, as recommended below.

in addition, many issues should be considered when CCRs are used in reclamation. The following are some examples:

- Do the characteristics of the site and CCR material make mine placement a viable disposal option?
- Is simple backfilling mixed with mine spoil adequate or are more controlled placement approaches needed?
- Should the cementitious properties of the ash be enhanced to minimize interaction with groundwater?

Should the CCR be put down in small lifts and compacted to lessen its hydraulic conductivity and reduce contaminant transport?

- Can CCRs be emplaced in a manner that neutralizes acidity at the mine over the long term and reduces overall contaminant transport?
- Will placement of CCRs above the water table be sufficient to minimize contaminant transport, given local recharge *rates*?  
Are additional bonding or other financial assurances necessary to *cover* potential off-site contamination from CCRs?

Given the known impacts that can occur when CCRs react with water in surface impoundments and landfills, special attention should be paid in reclamation operations to the interactions of water with CCRs. **Specifically, the committee recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through CCRs.** Several methods are described for reducing the interaction of CCRs with water, including placement well above the water table, compaction and cementation, and the use of liners and low-permeability covers. In all cases, proper covers should be placed over CCRs to prevent erosion as well as root penetration by plants and subsequent upward mobilization of CCR constituents. However, the committee recognizes that none of these methods will totally prevent CCRs from coming into contact with infiltrating water.

## Monitoring

Monitoring is an essential tool to confirm predictions of contaminant behavior and detect if and to what extent contaminants are moving into the surrounding environment. Because SMCRA monitoring regulations *are* not very prescriptive, states have a great degree of flexibility and control, and monitoring programs required at CCR mine placement sites vary widely by state. *Based on its reviews of CCR post-placement monitoring at many sites visited during the course of this study, the committee concludes that the number of monitoring wells, the spatial coverage of wells, and the duration of monitoring at CCR minefills are generally insufficient to accurately assess the migration of contaminants.* Additionally, the committee found quality assurance and control and information management procedures for water quality data at CCR mine placement sites to be inadequate.

The committee believes that a more robust and consistent monitoring program is needed in situations involving CCR mine placement. **The committee recommends that the number and location of monitoring wells, the frequency and duration of sampling, and the water quality parameters selected for analysis be carefully determined for each site, in order to accurately assess the present and potential movement of CCR-associated contaminants.** Such an approach would also allow the specifics of the monitoring plan to be tailored to accommodate the unique combination of CCR characteristics, emplacement techniques, and overall site characteristics, while considering estimates of ecological and human health risks and the uncertainties in the site conceptual model.

Although monitoring plans should be site-specific, downgradient wells should be sited with an understanding of the travel times for contaminants to reach these monitoring

points. Depending on the individual site characteristics and the distances to downgradient wells, a longer duration of groundwater monitoring may be necessary at *some sites* to adequately assess the temporal release of contaminants, which can occur over several decades. To address these concerns, several monitoring points should be established along predicted flow paths that will yield early (i.e., during the established bonding period) information that can be used to confirm predicted CCR leachate transport. At least one well or lysimeter, and, preferably two, should be placed directly in the CCR to assess the field leaching behavior and confirm predicted contaminant flux. As part of the monitoring plan, quality assurance and control plans should be developed prior to CCR placement with clearly defined protocols for sampling and analysis, for data validation, and for managing systematic errors in analytical procedures.

### **Performance Assessment**

**The committee recommends that the disposal of CCRs in coal mines be subject to reasonable site-specific performance standards that are tailored to address potential environmental problems associated with CCR disposal.** In areas where CCR leachate may interact with surface water (directly or through groundwater interaction), more stringent requirements may be necessary to protect aquatic life. Where violations of permit requirements or exceedances of performance standards occur, authority for appropriate penalties or corrective actions must be available to mitigate the damage and prevent future violations.

### **CCR Use in Abandoned Mine Lands and Re-mining Sites**

Any regulatory standards for CCR use adopted under SMCRA for active coal mining would most likely apply to re-mining activities but would not apply directly to CCR use in abandoned mine lands. To ensure adequate protection of ecological and human health, **the committee recommends that placement of CCRs in abandoned and re-mining sites be subject to the same CCR characterization, site characterization, and management planning standards recommended for active coal mines.** However, when developing performance standards, adequate consideration should be given to the significant differences between active mines, abandoned mines, and the re-mining of previously abandoned mine sites. At such abandoned mine sites, the CCR placement process begins with a degraded site, and the same management options available in an active mine site may not always be feasible. The plans should consider the benefits of CCR use for reclamation at these degraded sites but should also factor in the potential adverse impacts of CCRs.

## OVERARCHING ISSUES AND CONCERNS

### Research

The committee considered a variety of information in its deliberations, including: published technical reports; letters and reports (in both final and draft form); data compilations (both formal and informal materials); and other materials from citizens' groups, industry groups, and state and federal regulatory agencies. Much remains unknown about the long-term behavior of CCRs and their potential impacts in the mine setting. In addition, predictive characterization tools (e.g., leaching tests) are not adequate to guide management decision-making. Available information is typically from short-term field or laboratory-based studies. In many cases there were differences in interpretation of the data and, in several cases, clear discrepancies in the data themselves. The committee often found itself wanting additional information that was not available.

**The committee recommends that research be conducted to provide more information on the potential ecological and human health effects of placing CCRs in coal mines,** Specific attention in such a research program should be directed at improved understanding of the following:

1. The environmental behavior of CCR at mine sites, including under differing climatic and geologic settings, so that the types of mine settings, CCRs, and placement techniques most protective of human and ecological health can be identified. This research should include studies to determine under what conditions CCRs can effectively ameliorate the adverse effects of acid mine drainage (AMD) in surface waters, particularly over protracted time scales. This research should also include the application of existing reactive transport models to CCR mine placement sites to evaluate whether the transport and reaction processes in the model adequately describe the processes taking place at CCR mine disposal sites, including those processes that occur over protracted time scales.
2. The potential ecological and human health effects of placing CCR in coal mines—this program should include studies to clarify the fate and transport of contaminants from CCRs and the potential for human exposure from contaminated drinking water. It should include studies to determine the effects (or lack thereof) on biological communities over protracted time scales in mine placement sites where nearby streams or wetlands are likely to be connected to groundwater.
3. The continuous improvement and field validation of leaching tests to better predict the mobilization of constituents from CCRs in mine settings—specifically, post-placement field studies should be conducted that would allow the comparison of leaching test results to detailed water quality monitoring,

## Public Participation

In recognition of public concern over the potential for adverse environmental and health impacts from improper CCR disposal, government agencies responsible for regulating CCRs should ensure that the public receives adequate advance notice of any proposals to dispose of CCRs in mine sites. **The committee recommends that any proposal to dispose of substantial quantities of CCRs in coal mines be treated as a "significant alteration of the reclamation plan" under SMCRA.** This will ensure that the public is afforded adequate notice and an opportunity to officially comment on the CCR placement proposal.

## Alternatives for Regulatory Authority

The SMCRA and the Resource Conservation and Recovery Act (RCRA) are the basic federal laws for mine reclamation and environmental protection that can be applied to placement of CCRs in coal mines. Activities such as mining and environmental protection involve locally specific conditions that can be difficult to address through national rules. Hence, many federal programs are delegated to the states for their implementation to enable more focused incorporation of local conditions and needs. Neither SMCRA nor its implementing regulations, however, currently address the use or placement of CCRs in an explicit manner. As a consequence, states vary in their approach and in the rigor with which they address CCR use in mines.

After reviewing the laws and other relevant literature, *the committee concludes that although SVC.RA does not specifically regulate CCR placement at mine sites, its scope is broad enough to encompass such regulation during reclamation activities.* Furthermore, while SMCRA and its implementing regulations indirectly establish performance standards that could be used to regulate the manner in which CCRs may be placed in coal mines, neither the statute nor those rules explicitly address regulation of the **use** or placement of CCRs, and some states have expressed concern that they do not have the authority to impose performance standards specific to CCRs. Therefore, **the committee recommends that enforceable federal standards be established for the disposal of CCRs in minefills.** Enforceable federal standards will ensure that states have adequate, explicit authority and that they implement adequate minimum safeguards. As with current federal regulations, these rules should provide sufficient flexibility to allow states to adapt permit requirements to site-specific conditions, while providing the needed focus on the protection of ecological and human health.

There are three primary regulatory mechanisms that could be used to develop enforceable standards:

- + Changes to SMCRA regulations to address CCRs specifically;
- Joint Office of Surface Mining (OSM) and EPA rules pursuant to the authority of SMCRA and RCRA; or
- + RCRA-D rules that are enforceable through a SMCRA permit.

Under SMCRA, the OSM and related state agencies that implement SMCRA currently have the regulatory framework in place to deal with CCRs used in mine reclamation, and

have considerable expertise in review, permitting, and management of mine lands. On the other hand, under RCRA, EPA and its counterpart state and local agencies have developed significant technical and regulatory expertise in monitoring and oversight of waste disposal operations (e.g., landfills) that involve groundwater and toxic substances. Regardless of the regulatory mechanism selected, coordination between OSM and EPA efforts is needed, and would foster regulatory consistency with EPA's intended rule-making proposals for CCR disposal in landfills and impoundments.

In all cases, guidance documents will also be necessary to help states implement their responsibility for managing CCR. However, guidance alone is not adequate to achieve the needed improvements in state programs for CCR minefills. Only through enforceable standards can acceptable minimum levels of environmental protection from CCR placement in coal mines be guaranteed nationally.

## **CONCLUSIONS**

The committee believes that placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material. In such situations, however, an integrated process of CCR characterization, site characterization, management and engineering design of placement activities, and design and implementation of monitoring is required to reduce the risk of contamination moving from the mine site to the ambient environment. Enforceable federal standards are needed for the disposal of CCRs in minefills to ensure that states have specific authority and that states implement adequate safeguards.