

# Dust Mitigation Methods for Coal Combustion Products

2013 TECHNICAL REPORT



# *Dust Mitigation Methods for Coal Combustion Products*

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## Abstract

Coal-fired power plants generate coal combustion products (CCPs) requiring management for storage and disposal. These products are often stored in facilities such as landfills or placed in temporary storage pads for short or long durations. At these facilities, there is a need to address dust mitigation concerns in order to comply with environmental permits, maintain operational controls, and minimize disturbance to adjacent areas and the public. Dust mitigation approaches considered in this report consist of cover methods, operational methods, and physical barriers. This study focuses primarily on existing and commonly employed practical techniques, but also includes some new and innovative methods. These dust mitigation approaches are assessed against criteria such as general performance, initial application requirements, capital costs, operation and maintenance requirements, integrity in extreme weather, and secondary effects (other than dust mitigation). The report documents the drivers for dust control, outlines key assumptions, and provides a discussion of each dust mitigation approach in terms of its suitability for CCP storage sites.

### **Keywords**

Coal combustion products  
Disposal site  
Dust  
Dust control  
Storage site



# Table of Contents

<b>Section 1: Introduction .....</b>	<b>1-1</b>
Purpose of Study .....	1-1
Organization of Report.....	1-2
<b>Section 2: Coal Combustion Products and Facility Types.....</b>	<b>2-1</b>
Coal Combustion Products .....	2-1
Fly Ash .....	2-1
Flue Gas Desulfurization (FGD) Materials .....	2-2
Bottom Ash .....	2-2
Applications/Facilities for Dust Mitigation Approaches.....	2-3
Criteria for Dust Mitigation Approach Assessment.....	2-3
Criterion No. 1: General Performance .....	2-4
Criterion No. 2: Initial Application Requirements.....	2-5
Criterion No. 3: Capital Costs .....	2-6
Criterion No. 4: Operation and Maintenance Requirements.....	2-7
Criterion No. 5: Integrity in Extreme Weather .....	2-7
Criterion No. 6: Secondary Effects .....	2-9
<b>Section 3: Dust Mitigation Methods and Assessment.....</b>	<b>3-1</b>
Cover Approaches .....	3-2
Material Covers.....	3-2
Surface Encrusting Covers.....	3-4
Other Covers .....	3-4
Applications for Cover Approaches .....	3-5
Criteria Assessment for Cover Approaches .....	3-6
Operational Approaches .....	3-11
Surface Wetting .....	3-11
Other Operational Approaches.....	3-13
Applications of Operational Approaches.....	3-14
Criteria Assessment for Operational Approaches.....	3-14
Physical Barriers .....	3-17
Dust Screens .....	3-17
Roofed Structures .....	3-18
Silos.....	3-18

Natural Barriers.....	3-18
Applications of Physical Barriers.....	3-18
Criteria Assessment for Physical Barriers.....	3-19
Dust Mitigation Approach Assessment Summary.....	3-21
Wet Storage.....	3-31
Mixing and Stabilization.....	3-31

## List of Tables

Table 2-1 General Performance Ratings Definitions .....	2-5
Table 2-2 Construction Requirements Ratings Definitions .....	2-5
Table 2-3 Material Availability Ratings Definitions.....	2-5
Table 2-4 Labor Requirements Ratings Definitions .....	2-6
Table 2-5 Duration of Application Ratings Definitions .....	2-7
Table 2-6 Complexity of Application Ratings Definitions.....	2-7
Table 2-7 Freezing Temperatures Ratings Definitions .....	2-8
Table 2-8 High Winds Ratings Definitions .....	2-8
Table 2-9 Drought (hot and dry) Ratings Definitions .....	2-8
Table 2-10 Excessive Precipitation Ratings Definitions.....	2-8
Table 2-11 Reuse of On-Site Materials Ratings Definitions .....	2-9
Table 2-12 Leachate Generation Ratings Definitions .....	2-9
Table 2-13 Impact to Design Ratings Definitions.....	2-10
Table 2-14 Erosion Ratings Definitions .....	2-10
Table 3-1 Applications for Cover Approaches .....	3-6
Table 3-2 Applications for Operational Approaches.....	3-14
Table 3-3 Applications for Physical Barriers.....	3-19
Table 3-4 Short-Term Storage Pad Dust Mitigation Analysis Summary (Cover Approaches).....	3-22
Table 3-5 Short-Term Storage Pad Dust Mitigation Analysis Summary (Operational Approaches) .....	3-23
Table 3-6 Short-Term Storage Pad Dust Mitigation Analysis Summary (Physical Barriers).....	3-24
Table 3-7 Short-Term Landfill Dust Mitigation Analysis Summary (Cover Approaches) .....	3-25
Table 3-8 Short-Term Landfill Dust Mitigation Analysis Summary (Operational Approaches) .....	3-26

Table 3-9 Short-Term Landfill Dust Mitigation Approach  
Summary (Physical Barriers) .....3-27

Table 3-10 Long-Term Landfill Dust Mitigation Analysis  
Summary (Cover Approaches) .....3-28

Table 3-11 Long-Term Landfill Dust Mitigation Analysis  
Summary (Operational Approaches) .....3-29

Table 3-12 Long-Term Landfill Dust Mitigation Analysis  
Summary (Physical Barriers).....3-30



# Section 1: Introduction

Coal-fired power plants generate coal combustion products (CCPs) that require management for storage and final disposal. These materials, whether destined for beneficial reuse or permanent disposal, are typically staged in short-term storage pads and/or placed in landfills. Dust mitigation is a concern at these facilities, which must address compliance with environmental permits, potential disturbances to adjacent areas or the public, and the need to maintain general operational controls.

There are many approaches that utilities utilize in order to mitigate fugitive dust generation. These approaches depend primarily on climate, weather, capital costs, and CCP characterization. Dust mitigation approaches range from simple, traditional methods (e.g., spraying water) to more technologically advanced approaches (e.g., application of a polymer emulsion). Some dust mitigation approaches employ operational changes such as the minimization of the working face at a landfill, a lightweight building over a short-term pad, or additional water conditioning prior to delivery to the storage facility or placement in a landfill.

The choice of an appropriate dust mitigation approach or combination of approaches for a specific application is not always a straightforward process and may be influenced by seasonal or weather considerations, operational procedures, or multiple changes in plant operations.

## **Purpose of Study**

The purpose of this study is to summarize existing and practical approaches to dust mitigation and provide an assessment of each for comparison. The evaluation of these approaches is presented in order to provide a general overview aiding in the selection of an appropriate dust mitigation method. The assessment of these approaches is based upon:

- The investigator's technical experience acquired at utilities across the United States
- Discussions with vendors, manufacturers, and contractors
- Literature and web-based research

This study identifies a number of dust mitigation approaches that are analyzed against a set of standard evaluation criteria, including capital costs, operation and

maintenance, performance in various weather conditions, and application requirements. A general discussion and assessment is provided for the dust mitigation approaches. This assessment is summarized in tables provided for several dust mitigation applications.

This report can be used in two primary ways:

1. As an overview of all dust mitigation approaches, providing a discussion and assessment of these approaches.
2. To serve as a reference material for evaluating applicability of dust mitigation approaches on a site-specific basis.

## **Organization of Report**

This report is organized into sections as follows:

Section 2 (Coal Combustion Products and Facility Types) provides a brief discussion of the CCPs included for the dust mitigation evaluations. The materials presented are fly ash, bottom ash, and flue gas desulfurization (FGD) materials. In addition, the types of facilities that receive these CCPs are introduced, as well as the short-term and long-term applications for various dust mitigation approaches. These facilities and associated applications are intended to be general in nature, accounting for a large number of typical applications for a utility. They include:

- CCP Storage Pads (short-term applications)
- CCP Landfills (short-term applications)
- CCP Landfills (long-term applications)

Section 2 also presents criteria by which each dust mitigation approach is assessed in this report. The criteria include characteristics such as general performance, operation and maintenance requirements, and integrity in extreme weather. The discussion is presented qualitatively and, where possible, quantitatively.

Section 3 (Dust Mitigation Methods and Assessment) presents the dust mitigation approaches for this study and the corresponding assessments, which are organized in three general categories as follows:

- Cover Methods
- Operational Approaches
- Physical Barriers

This section provides a discussion on how the dust mitigation approaches fare in regards to the criteria for assessment including relative comparisons of advantages and disadvantages.

Section 3 also presents tables that outline the general assessment of each dust mitigation approach in relation to the specific application. Each dust mitigation approach is given a general assessment (poor, fair, average, good, excellent) for all of the criteria considered for assessment as well as the sub-characteristics associated with each. These tables are as follows:

**Table 3-4: Short-Term Storage Pad Dust Mitigation Analysis Summary (Cover Approaches).** This table is a summary of the dust mitigation approach assessment for short-term storage pad cover approach applications.

**Table 3-5: Short-Term Storage Pad Dust Mitigation Analysis Summary (Operational Approaches).** This table is a summary of the dust mitigation approach assessment for short-term storage pad operational approach applications.

**Table 3-6: Short-Term Storage Pad Dust Mitigation Analysis Summary (Physical Barriers).** This table is a summary of the dust mitigation approach assessment for short-term storage pad physical barrier approach applications.

**Table 3-7: Short-Term Landfill Dust Mitigation Analysis Summary (Cover Approaches).** This table is a summary of the dust mitigation approach assessment for short-term landfill cover approach applications.

**Table 3-8: Short-Term Landfill Dust Mitigation Analysis Summary (Operational Approaches).** This table is a summary of the dust mitigation approach assessment for short-term landfill operational approach applications.


**Table 3-9: Short-Term Landfill Dust Mitigation Analysis Summary (Physical Barriers).** This table is a summary of the dust mitigation approach assessment for short-term landfill physical barrier approach applications.

**Table 3-10: Long-Term Landfill Dust Mitigation Analysis Summary (Cover Approaches).** This table is a summary of the dust mitigation approach assessment for long-term landfill cover approach applications.

**Table 3-11: Long-Term Landfill Dust Mitigation Analysis Summary (Operational Approaches).** This table is a summary of the dust mitigation approach assessment for long-term landfill operational approach applications.

**Table 3-12: Long-Term Landfill Dust Mitigation Analysis Summary (Physical Barriers).** This table is a summary of the dust mitigation approach assessment for long-term landfill physical barrier approach applications.





## Section 2: Coal Combustion Products and Facility Types

Coal combustion products that have the potential to generate fugitive dust are commonly stored on site or disposed of in landfills at a power generation facility. This section introduces the CCPs considered for this dust mitigation study, including their properties and characteristics. Typical facilities for CCP storage and disposal are identified in this section, as well as the common applications (short-term or long-term durations) for dust mitigation approaches. The criteria for the assessment of each dust mitigation approach are presented, along with the rating definitions associated with each method.

### **Coal Combustion Products**

After initial placement and compaction, CCPs may be susceptible to surface drying, depending upon environmental conditions. Dusting caused by surface drying is due to the nature of the CCPs, which are primarily composed of silt to sand-size particles.

The primary types of CCPs considered for this study were fly ash and flue gas desulfurization (FGD) materials. These two materials are commonly produced and can generate fugitive dust, primarily because of their large fraction of fine-grained particles. Bottom ash is generally coarser than either fly ash or FGD material, and is less prone to dusting; however, since a fraction of bottom ash consists of a fine gradation, this CCP can in some cases generate dusting issues. For this reason, bottom ash is also considered for this study. In some cases, as described in Section 3, bottom ash is used as part of a cover material to mitigate dust issues.

### **Fly Ash**

Fly ash, a product of coal combustion, is removed from the power generation plant exhaust gases primarily by electrostatic precipitators and baghouses. Very fine-grained material forms the basis of the fly ash's composition, containing mostly silica, with particles generally having a near spherical shape due to the long exposure to high temperatures (melting followed by surface tension effects). Fly ash tends to be a well-graded material and generally consists mostly of silt-sized and clay-sized glassy spheres, with a median particle size that typically ranges from 7 to 50  $\mu\text{m}$ . These fine-grained materials make fly ash very

susceptible to the effects of winds and other weather conditions that elevate the particles into the atmosphere. The coefficient of uniformity of the material typically ranges between 4 and 20, giving fly ash a consistency similar to talcum powder. An exception to the tendency of fly ash to create fugitive dust is the use of a coal combustion source that produces a Class C fly ash. Powder River Basin coal, which is commonly used for coal combustion, produces this type of fly ash. Class C fly ash has cementitious properties, and naturally crusts and hardens after being placed on a storage pad or landfill.

### **Flue Gas Desulfurization (FGD) Materials**

FGD materials are the products of a process used for reducing SO<sub>2</sub> emissions from the exhaust gas (or flue gas) system of a coal-fired boiler and are another source of fugitive dust generation. The physical nature of these materials varies from a wet sludge to a dry powdered material, depending on the FGD system and the dewatering process. The wet sludge from a lime-based reagent wet scrubbing process with inhibited oxidation is predominantly calcium sulfite (CaSO<sub>3</sub>•1/2 H<sub>2</sub>O). This material is thixotropic, and usually managed wet in a pond or partially dewatered and stabilized with fly ash and lime and managed in a landfill or as a structural fill. The wet product from limestone-based reagent wet scrubbing processes with forced oxidation is predominantly calcium sulfate (gypsum, CaSO<sub>4</sub>•2 H<sub>2</sub>O). This material is usually dewatered, by means of either gravity drainage or mechanical methods, and managed as a dry product in landfills or used in wallboard production. In addition, there are dry materials generated from the FGD spray dryer absorbers (SDA), which are usually captured in a baghouse. These materials consist of a mixture of sulfites, sulfates, and fly ash.

FGD sludge and gypsum consists of small, sand-sized material that is coarser than fly ash and can range in size from 1 to 100 µm. These materials do not generate as much dust as a typical fly ash, and actually have an ability to crust on a surface with proper compaction. SDA material is a mixture of calcium sulfite/sulfate and fly ash, and thus has similar texture to these materials. SDA material is typically in the silt size range (3.9–62.5 µm) and is similar in size to fly ash, making it very susceptible to fugitive dust generation as well. Actual particle size for all FGD materials is always dependent upon the specific combustion, collection system, and operations at the power generation plant.

### **Bottom Ash**

Bottom ash, although not a significant contributor to fine fugitive dust, is agglomerated ash particles, produced during coal combustion. These particles are too large to be lifted away by flue gases and settle by gravity to the bottom of the furnace. Bottom ash is coarse, with particle size ranging from a fine sand to a fine gravel (ranging from >200 sieve to 3/8 inch in size). When placed in a surface impoundment or storage pad, the finer particles can become segregated and concentrate at the surface, which in some cases can lead to fugitive dust generation under certain conditions.

## **Applications/Facilities for Dust Mitigation Approaches**

Dust mitigation approaches to control fugitive dust generation are applied in different manners for varying durations at either a storage facility or storage pad on-site. Each dust mitigation approach is used in certain applications (durations), depending upon its characteristics. The applications for dust mitigation are subdivided into two general categories based on the duration of application and the type of CCP storage facility:

1. Short-term Application: This condition represents an application with a short-term period of service. For this study, exposed area duration is not strictly defined; however, a short-term application is generally considered to be a duration of one day to approximately 30 consecutive days.
2. Long-term Application: This condition represents an application with a longer-term period of service. For this study, exposed area duration is not strictly defined; however, a long-term application is generally considered one month to one year.

For periods of time greater than one year, it is assumed that at some point either the area of storage will be removed, or in the case of a landfill, a final cover will be applied. Final covers for landfills are not included in this assessment.

With regard to the types of storage facilities considered, the study includes a storage pad or a landfill (dry disposal). A CCP storage pad includes any management area, either enclosed or open to air, used as a storage area for CCPs prior to permanent placement or use. Storage pads are relatively small in area with routine CCP addition and removal, and therefore generally require short-term applications. In some instances, storage pads may remain in a static condition for a longer period and may be considered a long-term application as well. It should be noted that permit conditions may dictate the duration that a material can be stored in the pad, and this should be taken into consideration.

CCP landfills may require either short-term applications in active phases of landfill development (within or adjacent to the working face), or long-term applications in phases that are temporarily inactive and/or are awaiting final cover.

CCP impoundments (ponds) are also considered in this study, but are presented separately at the end of Section 3 of this report. At most active ponds, dusting issues can be avoided by maintaining a pond water level that minimizes exposed CCP. At inactive ponds, or those with exposed deltas that cannot be submerged, the dust mitigation options are generally the same as those for long-term exposed landfill areas, provided they are accessible by the necessary equipment.

## **Criteria for Dust Mitigation Approach Assessment**

In order to provide an assessment of the dust mitigation approaches, specific criteria have been selected that exhibit the characteristics of the methods. These criteria facilitate the assessments, which display the various strengths,

weaknesses, and other characteristics associated with the dust mitigation techniques. This assessment presents distinguishing characteristics, which are used to pair dust mitigation approaches with appropriate uses. The criteria are described later in this section, and are as follows:

1. General Performance
2. Initial Application Requirements
3. Capital Cost
4. Operations and Maintenance Requirement
5. Integrity in Extreme Weather
6. Secondary Effects

A subjective rating system was used to evaluate the dust mitigation approach against each of these criteria:

- **Poor:** Dust mitigation approach performs poorly relative to the other approaches for the specific criteria category in question.
- **Fair:** Dust mitigation approach does not perform well relative to the other approaches for the specific criteria category in question.
- **Average:** Dust mitigation approach performs on par with the other approaches for the specific criteria category in question.
- **Good:** Dust mitigation approach performs well relative to the other approaches for the specific criteria category in question.
- **Excellent:** Dust mitigation approach performs at the highest level relative to the other approaches for the specific criteria category in question.

The following discussion provides an overview of these criteria and defines the rating system used for the assessment of each.

### ***Criterion No. 1: General Performance***

The general performance was assessed for each dust mitigation approach for normal weather conditions. General performance is a qualitative measure of the overall ability of the method to suppress fugitive dust under favorable conditions.

The ratings definitions for the assessment of general performance are listed in Table 2-1.

Table 2-1  
General Performance Ratings Definitions

<b>General Performance (Fugitive Dust Control)</b>	
<b>Rating</b>	<b>Description</b>
Poor	Significant fugitive dust can potentially be generated
Fair	-
Average	Minimal fugitive dust can potentially be generated
Good	-
Excellent	No appreciable dust generation

**Criterion No. 2: Initial Application Requirements**

The initial application requirements refer to the difficulty and resource requirements associated with the first-time use. Initial application requirements include, but are not limited to, construction requirements (equipment requirements, application time, cure time, construction, staging, instruction, and difficulty), the availability of materials on-site, and labor requirements. More extensive application requirements will receive a lower rating, while limited application requirements will receive a higher rating. The ratings definitions for the assessment of initial application requirements are listed in Tables 2-2 through 2-4.

Table 2-2  
Construction Requirements Ratings Definitions

<b>Construction Requirements</b>	
<b>Rating</b>	<b>Description</b>
Poor	Significant construction activities
Fair	-
Average	Minimal construction activities
Good	-
Excellent	No construction activities

Table 2-3  
Material Availability Ratings Definitions

<b>Material Availability</b>	
<b>Rating</b>	<b>Description</b>
Poor	No on-site materials
Fair	-
Average	Moderate amount of application materials found or generated on-site
Good	-
Excellent	Significant amount of application materials found or generated on-site

Table 2-4  
 Labor Requirements Ratings Definitions

Labor Requirements	
Rating	Description
Poor	Requires contracted services
Fair	-
Average	Two or more workers
Good	-
Excellent	One worker

**Criterion No. 3: Capital Costs**

Estimated capital costs were developed for the initial application of a dust mitigation method. Rating definitions are not defined for this criterion—only unit costs are provided. Capital costs for the initial application are defined as the costs to attain the equipment and materials necessary for implementation of the approach. They are based on a general set of assumptions that apply as appropriate:

- Capital costs account for a one acre application.
- For approaches that are installed by a specialty contractor (and not by internal labor), installed costs are considered in the capital costs.
- Borrow soil is assumed to be located no more than one mile from the storage site.
- No costs are associated with the reuse of materials produced on-site at the plant (soil, bottom ash, wastewater, water, FGD materials, and fly ash).
- Equipment needed to support dust mitigation activities, such as water trucks, were not included in the estimated costs assuming that these trucks would be present at the site for other purposes. In the event that a truck would be needed, a one time capital cost can be anticipated as noted herein.
- Internal labor costs are not included for approaches applied by internal labor. It should be noted that placement of soil or similar materials would be performed by operations and the costs are therefore not included.
- Costs presented are based on experience and information identified during research. Given the range of values used, a specific contingency for site-specific and ancillary items was not included, but rather the costs present a base case range.

Costs for re-applications of the approach are the same cost as an initial application, and were not included in the capital costs, but were considered qualitatively in the Operations and Maintenance (see next section). Costs for the operation and maintenance of physical barriers (dust screens, silos, roofed structures, natural barriers) differ on a case-by-case basis, and are not investigated further in this report.

Capital cost information was generated through information from the following sources: URS Corporation project experience, Midwest Industrial Supply (Canton, OH), Selby's Soil Erosion Control (Newcastle, CA), Aquatrols (Paulsboro, NJ), Infrastructure Materials Corporation (Reno, NV), Duda Diesel (Madison, AL), Action Sports Netting (Port St. Lucie, FL), and A.M. Leonard (Piqua, OH).

**Criterion No. 4: Operation and Maintenance Requirements**

Operation and maintenance (O&M) requirements refer to the frequency and complexity of ongoing activities needed to maintain the control method. O&M requirements include, but are not limited to, frequency of application, labor requirements, equipment requirements, application time, cure time, and difficulty. For this evaluation, equipment is assumed to be automated or manually operated machinery (not tools) that are used to assist in the operation and maintenance of the dust mitigation approach. More extensive O&M requirements will receive a lower rating, while limited O&M requirements will receive a higher rating. The ratings definitions for the assessment of operation and maintenance are listed in Tables 2-5 and 2-6.

*Table 2-5  
Duration of Application Ratings Definitions*

<b>Duration of Application</b>	
<b>Rating</b>	<b>Description</b>
Poor	Frequent re-application
Fair	-
Average	Occasional re-application
Good	-
Excellent	No re-application required

*Table 2-6  
Complexity of Application Ratings Definitions*

<b>Complexity of Application</b>	
<b>Rating</b>	<b>Description</b>
Poor	Significant equipment and preparation required
Fair	-
Average	Moderate equipment and preparation required
Good	-
Excellent	No equipment and preparation required

**Criterion No. 5: Integrity in Extreme Weather**

The general performance in extreme weather conditions refers to the effectiveness of dust suppression during climatic or seasonal extremes in weather. The performance of each approach is rated for the following weather conditions that are considered extreme in comparison to normal conditions: extremely dry

(desert-like) conditions, extremely cold (below freezing) conditions, extreme winds (flat plain geography), and excessive precipitation. The ratings definitions for the assessment of integrity in extreme weather are listed in Tables 2-7 through 2-10.

*Table 2-7  
Freezing Temperatures Ratings Definitions*

<b>Freezing Temperatures</b>	
<b>Rating</b>	<b>Description</b>
Poor	Cannot be used or requires frequent complete re-application
Fair	Requires areas of re-application
Average	Requires maintenance
Good	Requires little maintenance
Excellent	No maintenance required

*Table 2-8  
High Winds Ratings Definitions*

<b>High Winds</b>	
<b>Rating</b>	<b>Description</b>
Poor	Cannot be used or requires frequent complete re-application
Fair	Requires areas of re-application
Average	Requires maintenance
Good	Requires little maintenance
Excellent	No maintenance required

*Table 2-9  
Drought (hot and dry) Ratings Definitions*

<b>Drought (hot and dry)</b>	
<b>Rating</b>	<b>Description</b>
Poor	Cannot be used or requires frequent complete re-application
Fair	Requires areas of re-application
Average	Requires maintenance
Good	Requires little maintenance
Excellent	No maintenance required

*Table 2-10  
Excessive Precipitation Ratings Definitions*

<b>Excessive Precipitation</b>	
<b>Rating</b>	<b>Description</b>
Poor	Cannot be used or requires frequent complete re-application
Fair	Requires areas of re-application
Average	Requires maintenance
Good	Requires little maintenance
Excellent	No maintenance required

## **Criterion No. 6: Secondary Effects**

Secondary effects (effects other than dust mitigation) are analyzed for each dust mitigation approach. Secondary effects for the purpose of this study include, but are not limited to, the reuse of on-site materials for the dust mitigation approach, the approach's effects on leachate generation, and the approach's impact on design. Dust mitigation approaches that reuse existing materials available on-site receive a higher rating, while dust mitigation approaches that use fewer on-site materials or none at all receive a lower rating. The effect on leachate generation by the specific approach is also considered. Dust mitigation approaches that decrease the amount of leachate generation receive a higher rating, while those that do not affect leachate generation quantity or negatively impact leachate quality receive a lower rating. Impact on design can include additional material in storage/landfill, additional leachate treatment, site design and layout to accommodate the implementation of the approach, and additional permitting associated with disposal or leachate modifications. All characteristics correspond to higher ratings due to positive outcomes. The ratings definitions for secondary effects are listed in Tables 2-11 through 2-14.

*Table 2-11  
Reuse of On-Site Materials Ratings Definitions*

<b>Re-use of On-Site Materials</b>	
<b>Rating</b>	<b>Description</b>
Poor	None
Fair	-
Average	Comprised of a portion of on-site materials
Good	-
Excellent	Comprised predominantly of on-site materials

*Table 2-12  
Leachate Generation Ratings Definitions*

<b>Leachate Generation</b>	
<b>Rating</b>	<b>Description</b>
Poor	Potential negative impact on leachate quality
Fair	-
Average	No impact on leachate quantity or quality
Good	-
Excellent	Significantly minimizes leachate generation

Table 2-13  
*Impact to Design Ratings Definitions*

<b>Impact to Design</b>	
<b>Rating</b>	<b>Description</b>
Poor	Significant impact to design
Fair	-
Average	Moderate impact to design
Good	-
Excellent	No impact to design

Table 2-14  
*Erosion Ratings Definitions*

<b>Erosion</b>	
<b>Rating</b>	<b>Description</b>
Poor	Significant increase in erosion
Fair	-
Average	Moderate increase in erosion
Good	-
Excellent	No impact to erosion



## Section 3: Dust Mitigation Methods and Assessment

Many dust mitigation approaches are utilized by power companies in order to comply with environmental regulations and protect power plant property and adjacent public areas. As part of this study, a large number of dust mitigation approaches were identified for further evaluation. These approaches were reviewed and combined into the final set of applications that are practical, common, and effective.

This section is intended to provide a description of each of the dust mitigation methods and an assessment based on the criteria outlined in Section 2. The dust mitigation techniques chosen for study are grouped into the following main categories:

1. Cover Approaches
2. Operational Methods
3. Physical Barriers

For each of these categories, the individual approaches are introduced and the applications for each approach are provided in a table. Each of the methods is described, including aspects of their implementation, applications suited for their use, and pros/cons associated with each. A narrative is presented for the assessment, organized by the criteria, noting how each of the techniques performs in relation to the specific criterion. Finally, assessment tables are provided at the end of each section, summarizing the assessment of each dust mitigation approach. These tables include the capital costs pertaining to each approach, and how the approach fares (Poor, Fair, Average, Good, Excellent) for each of the given characteristics.

In addition, a separate discussion on wet storage of CCPs in an impoundment (pond) is provided at the end of this section.

It should be noted that the dust mitigation approaches presented here do not all serve in the primary function to control dusting. For several of the approaches, dust mitigation is a beneficial outcome of a decision made due to other driving factors. These approaches are included for completeness in the evaluation.

## **Cover Approaches**

Cover approaches encompass methods that utilize a physical cover over the CCP materials, and can include both natural materials and synthetic materials, each in varying degrees of thickness and surface treatment. The cover approaches act as a shield or containment for the CCP materials against environmental conditions. A total of nine (9) cover approaches considered for this study are listed below:

- Material Covers
  - Soil Cover
  - Vegetated Soil Cover
  - Direct Seeding
  - Straw Cover
  - Bottom Ash Cover
- Surface Encrusting Covers
  - Water and Lime Solution
  - Polymer Emulsions
- Other Covers
  - Geosynthetic Fabrics
  - Erosion Control Matting

### **Material Covers**

Material cover approaches utilize a low-cost, natural or synthetic material for covering CCPs, either overnight or on a long-term basis. Material covers for this study include soil, vegetated soil, bottom ash, straw, and direct seeding covers.

#### **Soil Covers**

A moist soil cover is a traditional means of cover that utilizes any type of soil typically found adjacent to or nearby a storage facility. There are no highly specific requirements with regard to soil material type and quantity, and the soil is applied to the surface after CCP materials have been placed. In some cases, this is used as a short-term cover, which eliminates exposure of CCP materials to the air during periods of non-operation. In addition, soil covers may need to be removed prior to subsequent lifts in order to maximize storage capacity or to reuse materials. It can be a challenge in some cases to remove soil cover and reuse for subsequent lifts in a landfill. The operational efficiency associated with always keeping a soil cover in place (and placing subsequent CCPs on top of the soil) may overcome the economics associated with a shorter-lifespan storage facility. A soil cover is typically 6 inches in thickness, although this thickness may vary slightly from site to site. It should be further noted that soil covers, if applied for longer than a day, require occasional surface spraying in order to prevent fugitive dust generation from the soil itself.

## Vegetated Soil Covers

A vegetated soil cover is used as a long-term cover method for dormant areas of storage or a permanent solution for closure (when in compliance with permitted closure criteria). The established root systems associated with mature grass and vegetation keep the soil layer in place while minimizing erosion. A vegetated cover allows for rainfall storage capacity and evapotranspiration, both of which reduce infiltration into the storage facility and minimize erosion.

### Direct Seeding

Direct seeding is another method to attain a vegetated surface; however, this method applies vegetation directly on the CCP surface. Typically, this cover is achieved by hydroseeding – spraying a special mixture of slurry often comprised of water, seed, hydro-mulch, binders, and fertilizer. The advantage of a direct seeded cover in comparison to a vegetated soil cover lies in the labor and material costs saved by not establishing a soil cover prior to vegetation. The disadvantage of direct seeding is that there is a period of time before the seeds germinate and vegetation takes root. This period of time leaves the facility in a vulnerable condition to fugitive dust generation or erosion (washout) of the seeds, and timing must be selected carefully. Finally, a concern exists as to the presence of sufficient nutrients for the seeds to grow independently of a soil source, and this should be assessed on a case-by-case basis. Fly ash and other CCPs in general are low in carbon, and the carbon that does exist is difficult for plants to harvest. Vegetation that performs well in a high metals CCP environment must be selected in order to establish permanent cover. Grasses like *Festuca arundinacea* (a tall fescue species), for example, perform well in these conditions. They tend to uptake a small amount of metals and thrive for long periods in this type of environment.

### Straw

Straw is often used as a cover material at CCP storage facilities. A straw cover is typically spread by a straw blowing machine onto the surface for large areas. This material is spread directly onto the CCP surface to control fugitive dust generation, or to help establish the growth of vegetation on the surface. For small pads or small areas, straw may be spread by hand. Since straw has a tendency to be displaced under high winds, “straw crimping” is an additional application method that uses a mechanical roller to drive approximately 1/3 of the straw vertically into the surface. This method helps to keep a majority of the straw on the surface, protecting the surface against wind and erosion. In the case of smaller short-term storage pads where the use of a roller would not be feasible or practical, straw would be spread loosely by hand.

### Bottom Ash

A bottom ash cover is similar to a soil cover in that it utilizes materials that are easily attainable at a power plant, the key driver in the selection of this material. Like a soil cover, bottom ash must be transported to the storage site and applied

to the surface after CCP materials have been placed. Bottom ash is prone to dusting, however not to the extent of fly ash. At some plants, coarser bottom ash is segregated from the finer particles during the collection of the materials. This coarser material (usually collected near the inflow location of the pond or through a mechanical sorter/wash process) is less susceptible to dusting and is a better material for this and other uses. When a poorly graded bottom ash is used for this purpose, dusting is a concern that can be mitigated with a water spray application (discussed later in this section). A 6-inch bottom ash cover is assumed for this study, although actual thickness may vary by site.

### **Surface Encrusting Covers**

#### Water and Lime Solution

Surface encrusting cover approaches use a substance to help facilitate crusting on the surface of the CCP materials. This hardened surface inhibits fugitive dust generation under normal conditions. A water and lime solution spray is an example of a surface encrusting cover. In this method, lime (in a powdered form) is mixed with water in a tank to form a water-lime solution. This solution is sprayed onto CCPs and hardens the surface for fugitive dust control. This approach provides protection in areas exposed to high winds, as the lime acts as an encrusting agent, providing better protection than a water-only spray.

#### Polymer Emulsions

A polymer emulsion is a chemical agent that is either sprayed or spread on the surface. This method provides a crusted surface with excellent performance in most types of weather conditions, including wind, rain, and ultraviolet light. A polymer-emulsified surface tends to resist sink failures, breaking, or shifting. In addition, stormwater is prevented from infiltration and seepage into the encrusted surface. Common industry examples of polymer emulsion covers include Soil-Sement<sup>®</sup>, Gorilla Snot<sup>®</sup>, and Soiltac<sup>®</sup>. These surface encrusting agents are advantageous at facilities in which airspace requirements are a concern and/or material availability is limited. In addition, given the operational efficiency compared with other cover applications, polymer emulsions may be more favorable.

### **Other Covers**

#### Geosynthetic Covers

Geosynthetic fabrics encompass a variety of fabrics that can be placed over the CCP surface in sections. These sections of woven or non-woven fabric can either be placed in an overlapping fashion, or stitched together to provide a consistent surface cover for CCPs. As filling activities progress at a disposal facility, these covers can be moved around manually as necessary. Geosynthetic fabrics are thin and advantageous at facilities in which airspace requirements are a concern. They provide protection from weather, infiltration, and erosion in various applications.

## Erosion Control Matting

Erosion control matting is another variation of a cover approach. This fibrous blanket-like material is typically composed of biodegradable fibers and is often used to help establish vegetation. Structural stability and protection from wind and erosion can be provided in areas such as steep slopes, corners, and angular topography as the synthetic or biodegradable netting is pinned (or fastened) to the slope to allow the seeds already within the fabric to establish a solid, vegetated cover. The following are common examples in which the use of erosion control matting is advantageous. Erosion control matting is typically used for establishing seed and vegetation on an exposed surface, and is a common alternative to straw cover at sites that are exposed to high winds or contain steep slopes. Matting can also be used for short-term applications in providing cover to a surface only (no vegetation). A challenge associated with this approach is the time prior to seed germination and the establishment of vegetation. During this time, the CCP surface is vulnerable to erosion from both water and wind; however, the intent is that the netting will aid in the management of dusting issues and facilitate prompt vegetation growth. Like direct seeding, the timing of application must be chosen carefully to take advantage of optimal weather conditions.

### ***Applications for Cover Approaches***

Each of these material cover approaches (with the exception of bottom ash) can be used as a long-term dust mitigation solution for CCP landfill facilities. Many of these approaches are used for short-term applications at both landfills and storage pads.

In the case of a storage pad being managed to support a small volume of CCPs that are frequently accessed (CCPs added and removed), the frequent loading and loose nature of the materials would not promote the use of dust mitigation approaches that require access over the pad. However, for a storage pad managing CCP materials with a larger volume and intended for occasional access, the CCPs are often loosely compacted and would facilitate the placement of a cover system.

Vegetated soil covers, direct seeding, and erosion control matting were not considered appropriate methods for short-term applications because each involves the establishment of grass and vegetation on the surface, which typically takes 2-4 months to fully implement.

A summary of the cover approaches and their associated applications is provided in Table 3-1.

Table 3-1  
Applications for Cover Approaches

Dust Mitigation Approach	CCP Storage Pad Short Term	CCP Landfill Short Term	CCP Landfill Long Term
Soil Cover	✓	✓	✓
Vegetated Soil Cover			✓
Bottom Ash Cover	✓	✓	
Straw Cover	✓	✓	
Direct Seeding			✓
Water and Lime Solution	✓	✓	✓
Polymer Emulsion	✓	✓	✓
Erosion Control Matting			✓
Geosynthetic Fabrics	✓	✓	✓

### Criteria Assessment for Cover Approaches

#### General Performance

For long-term applications, polymer emulsions and vegetated soil covers perform best in terms of overall fugitive dust control for large areas. These methods are excellent approaches for dust control over areas that will remain idle or dormant for long periods of time. A water and lime solution cover also performs well, but it lacks the longevity and significant surface encapsulation that a polymer emulsion provides. Geosynthetic fabrics perform well for smaller areas of cover for both short-term and long-term applications. Larger areas are not well suited for geosynthetic fabrics because application becomes labor-intensive (application of strips and sections) and expensive.

Direct seeding covers also perform well due to the structure that mature vegetation provides on the surface. Erosion control matting and straw are good methods in the establishment of vegetation; however, when used alone they provide only fair performance in the control of fugitive dust. Both erosion control matting and straw covers alone work better for smaller areas in short-term applications. Erosion control matting and geosynthetic fabrics are advantageous for steep slopes and corners because the cover can be fastened into the surface, unlike most other applications, which have difficulty adhering and remaining in areas with such topography.

Soil covers (without vegetation) perform well due to the thickness (6 inches at a minimum) that the cover provides; however, fugitive dust can be generated from the soil itself as opposed to the CCPs, and this cover requires management. This approach works best in a humid environment or a region that does not experience dry spells. A bottom ash cover can generate fugitive dust in certain conditions

(high winds, for example), but in mild conditions the thickness and weight of the coarse CCP can largely preclude the release of fugitive dust from fly ash storage sites. The availability of bottom ash and the ability to dispose of it while using it as a cover make it an attractive cover approach alternative.

### Initial Application Requirements

Application requirements can vary among these approaches. The requirements for application of soil covers and bottom ash covers are similar: each requires heavy earth-moving equipment, including backhoe/excavator (from material source), off-road haul truck (to/from material source to storage site), spreader, and compactor. At least two laborers operating this equipment are required for these types of cover applications. Approaches that use devices to spread material across the surface include straw, direct seeding, water and lime solutions, and polymer emulsions. These methods typically require one to two laborers for application of the cover. Straw is spread through the use of a straw blowing machine, and seed is spread in a similar fashion. In the case of “straw crimping,” additional mechanical rolling equipment is needed to force portions of the straw into the surface. Hydroseeding and water and lime solutions are typically sprayed onto the surface by a hose that is connected to a large tanker truck containing the solution. Two laborers are required for the application of the methods. Polymer emulsions are typically applied by a tanker truck itself (equipped with a spray manifold on the rear of the truck) that applies the solution onto the surface. Vegetated surfaces require the appropriate mechanisms to spread material, like hydroseeding sprayers and straw blowing machines.

### Capital Costs

For purposes of this study, broad preliminary capital costs were developed for each of the cover approaches. Costs were developed to represent one acre of cover for the specific methods. The numbers represent the capital costs to obtain the material; transportation costs associated with getting the material to the site were not included in capital costs. It is assumed that a utility with a functioning power plant and disposal site will have the necessary equipment needed for application of these materials. Capital costs for initial applications only are as follows:

1. Soil Cover \$4,030 / acre  
(Costs include: soil excavation (for 6-inches of cover) within one (1) mile of storage facility and transportation to site).
2. Vegetated Soil Cover \$4,430 / acre  
Hydroseeded Soil Cover \$6,530 / acre  
(Costs include: soil excavation within one (1) mile of storage facility, transportation to site, and either seed or hydroseeding by contractor)
3. Bottom Ash Cover (none – material available on-site)
4. Straw Cover \$300 - \$700 / acre  
Straw Crimping \$1,000 - \$3,000 / acre  
(Costs include: straw and straw application with crimping performed by contractor)

- |  |                          |
|--|--------------------------|
| 5. Direct Seeding  | \$300 / acre             |
| Hydroseeding   | \$2,500 / acre           |
| Hydroseeding and Straw   | \$3,000 - \$4,000 / acre |
| (Costs include: seed materials only for direct seeding. Hydroseeding and straw applications performed by contractor)   |                          |
| 6. Water and Lime Solution   | \$560 / acre             |
| (Costs include: lime. It should be noted that the water truck for spraying, if not already owned by utility, can cost in the range of \$100,000 - \$200,000, depending upon size, condition, features, and on/off-road capabilities) |                          |
| 7. Polymer Emulsion (short-term)   | \$500 - \$1,000 / acre   |
| Polymer Emulsion (long-term)   | \$2,000 - \$3,000 / acre |
| (Costs include: polymer emulsion cover material and installation by contractor)  |                          |
| 8. Erosion Control Matting   | \$4,000 - \$7,000 / acre |
| (Costs include: erosion control matting material and installation by contractor)   |                          |
| 9. Geosynthetic Fabric   | \$6,000 - \$9,000 / acre |
| (Costs include: geosynthetic fabric material and installation by contractor)   |                          |

### Operation and Maintenance Requirements

Operation and maintenance requirements associated with cover approaches can differ; however, they are very similar in nature to the requirements of their initial application. The cover approach typically requiring the most maintenance is a straw cover. Straw, being a lightweight material, is susceptible to wind erosion and requires replacement as needed over large areas. Other than manual replacement of eroded areas of straw, binding agents can be applied to the straw in order to unite the straw as a unit and make it less susceptible to wind erosion. In addition, mechanical rollers that produce “straw crimping” may need to be driven over the surface on occasion.

Other cover methods requiring maintenance are soil covers and bottom ash covers. One drawback to these approaches is that in periods of dry weather (or in dry regions), the soil and bottom ash can dry out and can create fugitive dust of its own. This dusting is typically mitigated by water spraying on an as-needed basis, depending upon duration of exposure and weather conditions. Other spray agents such as surfactants or brines may be used in order to mitigate dusting as well. These agents are discussed later in this section.

Surface encrusting agents, such as water and lime solutions and polymer emulsions, typically do not require much maintenance. A polymer emulsion, once applied, lasts from six (6) months to over a year. This makes it an attractive option for use during dormant winter periods in northern climates. A water and lime solution under the influence of wind erosion and dry periods can slowly break up in certain areas, requiring re-applications from time to time.

Vegetated covers, when selected carefully with native grasses and plants, require little maintenance once the vegetation is established. When establishing vegetation, maintenance can include daily watering, especially in hot and dry regions. The establishment of vegetation is best in the spring or autumn, or periods of sustained mild temperatures. Direct seeding vegetated covers are the most difficult to establish, as the practice is relatively new and various forms of vegetation and fertilizers that perform well in coal ash are still being developed.

Geosynthetic fabrics, when placed according to manufacturers' instructions, stabilize the surface and typically do not require much maintenance. Erosion control matting is best used for the establishment of vegetation on the surface, as high winds can displace portions of matting when the matting alone is on the surface (without vegetation).

### Integrity in Extreme Weather

Of the various approaches, polymer emulsion covers perform best and hold up best in extreme weather, including drought-like periods of dry weather, freeze and thaw conditions, sub-freezing conditions, extremely windy conditions, and excessive rain. This is another reason why polymer emulsion covers work well for long-term applications. Established vegetated covers (with vegetation and established roots) also perform well for these types of extreme weather conditions. The root structure holds the surface in place, preventing both wind and water erosion. Unestablished vegetated surfaces (vegetation growing and in development) are susceptible to extreme weather events. The covers associated with establishing vegetation (erosion control matting, hydroseeding constituents, straw, etc.) are vulnerable to erosion and require areas of re-application until grasses are firmly established. It should be noted that these approaches must be established prior to winter and extended sub-freezing weather conditions, as their application typically must occur at temperatures above freezing.

Geosynthetic fabrics, as a cover that is applied in sections, are susceptible to high winds. The perimeter edges are most susceptible, along with other edges throughout the interior that are either overlapped or tied/melded together. This drawback makes geosynthetic fabrics best suited for smaller areas in either short-term or long-term applications.

Soil covers and bottom ash covers can be susceptible to excessive rain, excessive wind conditions, and periods that are extremely hot and dry. Fugitive dust can be created from the covers themselves during these periods, requiring maintenance. This makes a soil cover or bottom ash cover best for smaller areas and short durations of time, for example when used as daily/overnight covers for working areas of a landfill. To aid in the management of heavy weather conditions, soil covers are often pitched slightly and sealed (a smooth drum roller traverses the area and creates a slightly compacted surface) to aid in surface water runoff and discourage soil saturation.

Straw covers are vulnerable to extremely high winds, excessive rain, and periods that are extremely hot and dry. These types of weather events displace straw,

allowing fugitive dust creation. Straw covers are best suited for smaller areas and areas protected from wind for short-term durations. Binding agents sprayed directly on the straw surface and straw crimping, as discussed earlier, can help to hold straw surfaces together.

## Secondary Effects

Each of the cover approaches may have secondary effects associated with their use. Secondary effects may include leachate generation effects (additional leachate generation or reduced leachate generation), impacts to facility design (site layout or storage facility airspace impacts), erosion effects, the use and/or reuse of available on-site materials, and potential impacts on water quality, especially in regard to pending regulations for power plant wastewater effluent limitations guidelines (ELGs).

Cover approaches that use and/or reuse on-site materials include both soil covers and bottom ash covers. Soil, being readily available in and/or around a disposal facility, makes a common choice for cover. Bottom ash, in some cases already designated for disposal at the site, can be used as cover instead of bringing in outside materials.

Most cover approaches (with the exception of bottom ash) reduce leachate generation in some way. Those approaches that are typically used over large areas for long-term durations (polymer emulsions, water and lime solutions, vegetated soil covers) can reduce large amounts of leachate. Surface encrusting methods, such as polymer emulsions and water and lime solution covers, divert stormwater off the surface and into local catch basins and other storm drainage infrastructure. Vegetated soil covers hold stormwater and allow for evapotranspiration back into the atmosphere. Cover approaches used for smaller areas (geosynthetic fabrics, soil covers) also reduce leachate generation, but in smaller amounts due to area. Geosynthetic fabrics divert stormwater off the site and into local drainage infrastructure, while soil covers can hold stormwater and allow for evaporation into the atmosphere.

Stormwater runoff that is exposed to CCP materials and is conveyed by slope off the site must be identified, as it is a potential source for stormwater contamination. Cover approaches in which this may occur include bottom ash covers, direct seeding covers, straw covers, erosion control matting, and water and lime solution covers.

Airspace is a concern at disposal facilities, as the increased use of airspace affects its long-term life. Soil covers and bottom ash covers (typically 6 inches in thickness) can affect airspace and overall volume storage if these covers are not removed in any way prior to CCP placement.

Finally, some dust mitigation approaches can have an effect (positively or negatively) on site erosion. A soil cover or bottom ash cover can erode when left exposed in storm events, causing effects outside of the area of cover along with a reduction of the cover itself. Vegetated covers can sometimes erode in certain

extreme events, but typically are stable when populated with vegetation. A straw cover has a tendency to erode, especially when it is not crimped or covered by a binder material. Polymer emulsions, water and lime covers, and geosynthetic fabrics increase the amount of runoff generated from the area of cover, causing an increase in stormwater volume in another area of the disposal facility or site.

## **Operational Approaches**

Operational approaches consist of a variety of methods that utilize operational means to assist in suppressing fugitive dust generation. These methods are performed either at the power plant prior to transportation to the storage site, or at the storage site itself. A total of six operational approaches considered for this study are listed below.

- Surface Wetting
  - Water Spray
  - Brine Spray
  - Wastewater Spray
  - Surfactants
- Other Operational Approaches
  - Working Face Minimization
  - Increasing Moisture Content

### **Surface Wetting**

Controlling the moisture content of the CCP material is the most common method used to counteract fugitive dust. The control of moisture is accomplished through surface wetting approaches by spraying the CCP material at the storage site. The addition of moisture and weight to the surface of CCP materials creates a barrier and allows the surface particles to resist the impacts of wind erosion. The use of water spray on-site requires an operator on-site at all times for frequent re-applications, using either an off-road or a highway-type water truck depending on the weather conditions at the site and the frequency of disturbance to the area. This method provides a utility greater control and the ability to react to changing weather conditions immediately. Increasing the moisture content of the CCP material at the plant prior to transport—to below the upper end of the efficient range—is a low-cost alternative to dust suppression; however, if used exclusively, this leaves the CCP material oversaturated and difficult to manage and place. Increasing moisture content is discussed under Other Operational Approaches.

#### **Water Spray**

For the water spraying approach, a water tanker truck is typically filled up at the power plant by a local water source. The source of water can vary, but examples include the local municipal potable water supply, the power plant's water intake (river, lake), a local stormwater retention pond, or any other body of water located near or adjacent to the storage facility. The water tank is typically on-site

for the duration of facility operations, spraying the surface on an as-needed basis while materials are being spread and applied or shortly thereafter. The duration of a water spray application is short, depending upon wind conditions and temperature, and water is commonly reapplied every 1 to 2 hours during working operations.

### Brine Spray

Spraying the surface of CCP materials with a brine solution (typically consisting of at least 30 percent by weight of calcium chloride) is a method to improve upon a typical water spray application in order to control fugitive dust generation. Most chlorides are hygroscopic and absorb moisture and humidity from the atmosphere, creating a water barrier between the materials and the air. For this reason, liquid calcium chloride is commonly used on construction sites and applied to roadways, sidewalks, dirt roads, and driveways for dust control. When a brine solution is applied to the surface of CCP materials, the application draws moisture from the atmosphere, which lengthens the duration of each application. This barrier helps to prevent dust from being picked up by wind and becoming airborne. As in a water spray application, a water truck containing brine is located on-site and sprays the solution on the surface as the materials are being spread and applied. The brine spray may have a negative impact on leachate quality by increasing total dissolved solids and chloride levels.

### Wastewater Spray

Other sources of water that contain chlorides for spray applications are found within wastewater streams that occur as a result of coal combustion and CCP storage operations. In this way, the wastewater, a by-product in the plant, may be reused outside the treatment process. Spray applications provide an opportunity for wastewater stream reuse at a facility site. These wastewater streams include, but are not limited to, landfill leachate, FGD blowdown wastewater, decanted water from holding ponds, and other miscellaneous wastewater streams that may or may not be treated through a wastewater treatment system. Depending on wastewater characteristics, the use of raw wastewater for spray applications at a landfill has the potential to significantly impact the quality of the landfill leachate. As a result, the use of wastewater spray can potentially require additional leachate treatment prior to discharge. In addition, it should be noted that some states have regulations regarding recirculated wastewater or leachate. The use of treated wastewater streams minimizes water quality impacts on landfill leachate. Prior to the use of any treated or non-treated waste stream for spraying purposes, testing and research should be performed to determine if this source is a feasible solution for spraying purposes and if a permit modification is needed.

### Surfactants

The use of surfactants is another method used as a surface wetting approach. Surfactants are substances that are added to water in order to decrease the surface tension between water molecules, allowing droplets to spread out and wet a

greater surface area. Coal ash is hydrophobic, and has a tendency to repel water from its surface. When a surfactant is added to water, the surface tension of the water is lowered to that of coal ash, allowing better adsorption onto the surface. These substances can be added to water, and doing so enhances the ability of normal water sprays to wet, contact, and agglomerate and adsorb fine surface particles. This represents an improvement over regular water spray, creating a tacky spray substance that holds fine particles together, in some cases even after the solution has dried. The use of surfactants helps to decrease dust generation while using less water in the process.

### ***Other Operational Approaches***

There are two other operational approaches besides surface wetting that are used for dust suppression. One is referred to as working face minimization (at a landfill or dry storage facility) and the other is the increase in CCP moisture content at the power plant, prior to transportation to the dry storage site.

#### **Working Face Minimization**

The working face is the portion of the active fill area in a CCP storage facility where CCP materials are currently being placed, spread, and compacted. Decreasing the size of this working face and locating it in a position that protects it against wind and erosion aids in minimizing dust generation. This approach does not directly mitigate dust, but reduces the area from which fugitive dust can be generated. The incorporation of working face minimization techniques requires daily placement of materials while reducing the amount of time required for CCPs to dry and become susceptible to dust generation. This is an operational improvement with a secondary impact of reducing the dusting potential.

#### **Increasing Moisture Content**

Increasing the moisture content of CCP materials during or after collection at the power plant (prior to transportation to the storage site) is a method to reduce dust generation of the material. Fly ash is typically already moisture-conditioned at the power plant for operational reasons, but this approach takes it a step farther by moisture-conditioning the CCP material to a condition that is closer to the optimum moisture content for compaction. Often, the CCP materials are moistened at the plant to near the lower end of the moisture range, arrive at the site below optimum levels for compaction, and require water to reach optimum moisture content for placement. The intent in using this approach is to improve the saturation of the CCP materials upon arrival at the storage site such that they are less susceptible to dusting while remaining at an optimum level for compaction. Although this does not completely eliminate water spraying and moisture control at the storage site, it reduces the need for additional moisture conditioning (water spraying or other technique) on-site.

## **Applications of Operational Approaches**

Each of these operational approaches (with the exception of working face minimization) can be used to satisfy short-term dust mitigation concerns for both CCP storage pads and CCP landfills. The surface wetting approaches, as well as increasing the moisture content at the power generation facility, are limited to short-term applications only, due to evaporation. Working face minimization, a technique used for the daily operations of placement and compaction over the life of the landfill, is not considered an option for short-term storage pads. A summary of the operational approaches and their associated applications is provided in Table 3-2.

*Table 3-2  
Applications for Operational Approaches*

<b>Dust Mitigation Approach</b>	<b>CCP Storage Pad Short Term</b>	<b>CCP Landfill Short Term</b>	<b>CCP Landfill Long Term</b>
Water Spray	✓	✓	
Brine Spray	✓	✓	
Wastewater Spray	✓	✓	
Surfactants	✓	✓	
Working Face Minimization		✓	✓
Increasing Moisture Content	✓	✓	

## **Criteria Assessment for Operational Approaches**

### General Performance

Spraying water over CCPs during final placement of the materials into a landfill is the most common industry approach to fugitive dust suppression. This method is sufficient for dust suppression under normal conditions, so long as water and spray equipment is available on-site at all times during operations, for application on an as-needed basis. Additionally, in normal conditions, spraying water allows workers on-site to respond in a timely manner to reapplication needs as they arise. This approach, however, has its limitations, as surfaces can be exposed overnight. In hot and/or dry weather conditions in which water can evaporate quickly, this approach may be coupled with an overnight cover when the facility is not in operation, or it requires more frequent re-application. The use of brine, wastewaters, and surfactants can also help to extend the duration of a typical spray application and slow its evaporation into the atmosphere, but there may be environmental compliance concerns that need to be evaluated and appropriate permitting established.

Working face minimization techniques do not entirely eliminate dust generation, but they limit it by reducing the surface from which fugitive dust can originate in landfill operations. In addition, locating the working face in a manner that shields it from wind also helps to reduce dusting. This method is typically used in conjunction with another dust mitigation approach. For example, a smaller CCP working face, when coupled with spray applications, can eliminate most fugitive dust under normal working conditions. The reduced working face also limits the amount of water needed for a given spray application, and helps to reduce leachate generation.

### Initial Application Requirements

The initial application requirements can vary among these operational approaches. The simplest approach is the common water or wastewater spray method, which requires filling the water truck from the designated water source, and typically calls for one worker to both drive the truck and perform the actual application. This simplicity is another reason why water spray applications are so common. A brine spray or use of surfactants only requires the additional initial mixing of the substance into the water truck.

Landfill working face minimization requires upfront planning, engineering, and landfill cell design to properly incorporate the technique into the facility. This is an operational approach that impacts not only dusting reduction, but also leachate generation, improved placement, and efficient site management.

Increasing the moisture content of CCP materials at the power plant (rather than on-site at the storage facility) only requires the necessary moisture conditioning equipment to generate a moisture content greater than optimum for compaction. However, careful attention is required during the process in order not to oversaturate the materials or otherwise introduce concerns within the system.

### Capital Costs

For purposes of this study, broad preliminary capital costs were developed for each of the operational approaches. Costs were developed to represent one (1) acre of coverage for the specific operational methods. The numbers represent the capital costs to obtain the material; transportation costs associated with getting the material to the site were considered negligible. It is assumed that a utility with a functioning power plant and disposal site have the necessary equipment needed for application of these materials. Capital costs are as follows:

1. Water Spray (none – water available on-site)  
(Costs may include the purchase of a water spray truck, if the utility does not have one already, not shown above. Water trucks typically cost \$100,000 - \$200,000, depending upon size, condition, features, and on/off-road capabilities)
2. Brine Spray \$100 / acre  
(Costs include: brine. Water truck for spraying, if not already owned by utility, can cost in the range of \$100,000 - \$200,000.)

3. Wastewater Spray (none – wastewater available on-site)  
(Costs may include the purchase of a water spray truck, if the utility does not have one already, not shown above. Water trucks typically cost \$100,000 - \$200,000, depending upon size, condition, features, and on/off-road capabilities.)
4. Surfactants \$100 / acre  
(Costs include: surfactants. Water truck for spraying, if not already owned by utility, can cost in the range of \$100,000 - \$200,000, depending upon size, condition, features, and on/off-road capabilities.)
5. Working Face Minimization (none – this method incorporated into operations)
6. Increased Moisture Content (none – water available on-site)

### Operation and Maintenance Requirements

Operation and maintenance requirements for the spray methods (water, brine, wastewater, surfactants) are similar to those for the initial application. Simply, these approaches are re-applied on an as-needed basis throughout working operations. The spraying of water for dust mitigation allows workers on-site to respond in a timely manner to re-application needs as they arise. Of the spray methods, those with surfactants added tend to have the longest duration before a re-application is needed. The minimization of a working face may need maintenance during non-working hours, as the face may be left exposed to the weather and elements. In these cases, a short-term cover approach may be utilized on the exposed face.

### Integrity in Extreme Weather

Dry and drought-like conditions have a significant impact on surface wetting approaches. Due to the high evaporation rate associated with dry conditions, frequent re-applications are required with surface wetting approaches. The benefit of drawing moisture from the atmosphere that water containing chlorides (brine, wastewater) provides is relatively insignificant in dry conditions. Surfactants perform the best in dry conditions by keeping water at the surface for a longer time period; however, re-applications are still necessary. Extremely windy conditions have a significant impact on surface wetting approaches as well. Even when CCPs are wet and saturated, high winds can pick up surface particles. In addition, surface wetting approaches (and any other methods increasing the moisture content) are not generally used in freezing and/or sub-freezing conditions, as this causes damage to equipment rollers, other mechanical devices, and the CCP surface.

Working face minimization, although reducing the negative impacts of extreme weather conditions, in itself does not protect the exposed area of CCPs. Hot and dry conditions, along with high wind conditions, have an impact on the exposed area, and additional dust mitigation methods may need to be employed in these cases.

## Secondary Effects

All of the operational approaches to dust mitigation may have secondary effects associated with their use. Secondary effects include leachate generation effects (additional leachate generation or less leachate generation), impacts to facility design (site layout or storage facility airspace impacts), the use and/or reuse of available on-site materials, and impacts on water quality, especially in regard to pending regulations for power plant wastewater effluent limitations guidelines.

Although most water is lost to evaporation, surface wetting approaches tend to cause a minor increase in leachate generation as water is continually applied to the surface and some percolates its way down. The use of wastewaters and brine in spray applications may have a significant impact on leachate water quality. This approach may increase the chlorides in leachate, along with other constituents native to the specific wastewater stream. It should be noted that the newly proposed Effluent Limitations Guidelines Rule may affect leachate treatment in the near future. Utilities should be aware of impacts on leachate quality and future leachate treatment requirements before considering this method.

Erosion can result from surface wetting approaches, because the CCPs are left exposed to the atmosphere and the effects of severe precipitation events. Working face minimization techniques, due to the reduction in CCP exposed areas, reduce the amount of erosion occurring due to storm events.

## Physical Barriers

The construction of physical barriers at or around CCP storage facilities is another method of controlling fugitive dust generation. These barriers are constructed around the perimeter of the site and may be moved to follow the current working area within the facility. For circumstances in which a site is located near or adjacent to public areas, physical barriers can be used not only to control fugitive dust, but to provide a visual screen as well. Four types of physical barriers were considered for this study:

- Dust Screens
- Roofed Structures
- Silos
- Natural Barriers

### **Dust Screens**

Dust screens are large synthetic screens attached to regularly spaced poles fixed into the ground. They are used around the perimeter of CCP storage facilities to protect the area against wind and to contain fugitive dust within the storage facility site footprint. Steel or wooden vertical posts are spaced horizontally and connected by a screen/netting-type synthetic material that surrounds the disposal facility. In some cases, these screens are mobile and can be moved around the

storage facility to accommodate active areas. Dust screens typically range from 25 feet to 40 feet in height.

### ***Roofed Structures***

Roofed structures may be relatively small and house short-term CCP storage pads on a concrete pad with push walls. These facilities are usually used for operational purposes, storing CCP materials for short periods of time between material transports. Roofed structures, by their enclosed nature, serve as a dust mitigation method as well. Larger facilities may utilize an air-supported dome structure for permanent dust containment. In short-term or long-term applications, a lightweight roofed structure can be constructed over and around a short-term working area of a CCP storage pad to contain fugitive dust that is generated through regular movement by construction equipment. For storage pads that are larger in footprint and not impacted regularly with operational loading or unloading, the roofed structure may be a less appropriate solution.

### ***Silos***

Steel silos are completely enclosed structures typically used at power plants as short-term storage vessels for coal ash (typically fly ash only) prior to transport to a permanent location. While this is not their primary purpose, these structures protect materials from being exposed to weather elements. Dust mitigation is substantially suppressed using this approach.

### ***Natural Barriers***

Natural barriers are planted or placed around the perimeter of CCP storage facilities to protect the area against wind and to contain fugitive dust within the storage facility site footprint in a similar fashion to the dust screens. Examples include, but are not limited to, pine trees, other coniferous trees, bamboo, bushes, and raised/mounded earth.

### ***Applications of Physical Barriers***

Each of the physical barrier approaches can be used as dust mitigation for short-term CCP storage pads. Silos, for example, are usually found on-site at the power plant for temporary storage of fly ash prior to transportation to a final storage or reuse destination. A roofed structure is another place to temporarily store CCP materials prior to the final storage or reuse destination. Dust screens and natural barriers are typically used for more long-term applications, since many times these are permanent fixtures around a CCP storage facility or landfill. A summary of the physical barrier approaches and their associated applications is provided in Table 3-3.

Table 3-3  
Applications for Physical Barriers

<b>Dust Mitigation Approach</b>	CCP Storage Pad Short Term	CCP Landfill Short Term	CCP Landfill Long Term
Dust Screens	✓	✓	✓
Roofed Structures	✓		
Silos	✓		
Natural Barriers	✓	✓	✓

### **Criteria Assessment for Physical Barriers**

#### General Performance

For short-term applications, silos perform very well in terms of fugitive dust control. The enclosed structure protects the CCPs (usually fly ash) from the weather and elements. The only concern with the use of a silo arises during operation, when the opening/closing and truck filling can create fugitive dust. In conjunction with silos used in this manner, additional dust suppression or containment methods are implemented during loading of trucks.

Roofed structures also perform well for short-term storage pad applications, in particular as a temporary storage location prior to transport to final storage or reuse. The enclosed structure protects CCPs from all types of weather. For storage pads that are larger in footprint and are not impacted regularly with operational loading or unloading, the roofed structure may be a less appropriate solution. The smaller overall footprint of a silo gives it an advantage over a roofed structure if space is a concern, but the storage capacity is often the tradeoff.

Dust screens and natural barriers are fair solutions for normal conditions; however, they do not perform well during windy conditions. These barriers typically have a maximum height of around 40 feet and do not completely capture or control all fugitive dust, as winds can carry the dust to an elevation higher than the barriers. Since these methods are typically used as visual barriers to shield a facility from public areas or are located near developments, they are best used in conjunction with another dust mitigation approach to achieve better fugitive dust mitigation results.

#### Initial Application Requirements

Initial application requirements for physical barrier approaches are more intensive than for all other dust mitigation approaches, as these methods require careful planning, surveying, field investigations, engineering, design, and construction. These approaches require planning and scheduling in advance to account for incorporation into the site operation. Engineering for these types of facilities can also include structural, mechanical, and geotechnical design. Dust screens require significant construction activities in installing foundations and permanent posts

and screens around a part or parts of the storage facility. Roofed structures and silos are also significant engineering and construction projects. Some roofed structures include internal HVAC systems for airflow and generally require large clear spans leading to substantial steel beams for construction. Natural barriers are the easiest to achieve as design is less intensive, construction involves earth-moving activities and landscaping, and heavy construction is very limited. These approaches are assumed to be constructed by a hired contractor in all cases.

### Capital Costs

For purposes of this study, broad preliminary capital costs were developed for each of the physical barrier approaches. Costs were developed to represent one acre of cover for the dust screens and natural barriers. Roofed structures were assumed to be 100' x 100', or 10,000 square feet in area. Silos were assumed to be 350-ton capacity structures. The numbers represent the capital costs to construct these types of facilities. Approximate capital costs are as follows:

1. Dust Screens \$525,000 / acre coverage
2. Roofed Structures \$1,500,000 - \$2,500,000/structure
3. Silos \$300,000 - \$500,000 /structure
4. Natural Barriers \$25,200 / acre coverage

### Operation and Maintenance Requirements

An attractive quality of physical barriers, in comparison to other dust mitigation approaches, is that operation and maintenance requirements are minimal. Silos require little maintenance with respect to dusting issues (additional maintenance of the systems may be more substantial), except for valve repair and other mechanical replacements when necessary over the lifetime of the structure. Dust screens and natural barriers have the potential to be damaged during storms and may require some repair, but typically do not require maintenance. Roofed structures require little maintenance, except for cleaning and mechanical maintenance as required.

### Integrity in Extreme Weather

Extreme weather conditions like high winds, drought-like conditions, freezing and thawing, sub-freezing temperatures, and excessive precipitation typically do not have an effect on structures like a silo or a roofed structure. These approaches function very well for all types of conditions, and structures are advantageous over other dust mitigation methods in these types of weather conditions.

Extreme weather conditions can potentially have impacts on both natural barriers and dust screens. Drought-like conditions do not have an impact on a dust screen itself; however, the dry conditions can leave CCPs susceptible to wind erosion. High winds have the potential to impact dust screens and natural barriers at times, and may cause minor damage. Freezing temperatures and excessive rain do not have an effect on a dust screen.

Regarding natural barriers, drought-like conditions can dry out vegetation over time, requiring manual watering, maintenance, and care. The use of native vegetation is key in helping to mitigate the effects of the natural environment on vegetation. Extremely windy conditions can cause minor damage to vegetation, and of course can lead to significant fugitive dust generation. Freezing temperatures and excessive precipitation generally do not have an effect on vegetation, as long as proper vegetation is selected for the particular climate.

### Secondary Effects

There are very few secondary effects associated with physical barrier approaches, with impacts on design being an exception. Both silos and roofed structures minimize leachate generation and erosion because they shield CCPs from the elements. Natural barriers and dust screens, on the other hand, do not have the effect of minimizing leachate generation, as the CCP surfaces are exposed to the elements. In addition, erosion is not minimized in any way through the use of natural barriers and dust screens.

Each of these approaches has a significant impact on the design of a facility. Silos and roofed structures can affect site layout, as large areas are needed for their location and construction. Roofed structures and silos can entail geotechnical, structural, site/civil, and mechanical engineering. Preliminary studies for dust screens entail the identification of the local prevailing wind direction and wind speeds. Facility planning and engineering must take place prior to the addition of one of these structures to a site.

### **Dust Mitigation Approach Assessment Summary**

The following tables summarize the assessment of each dust mitigation approach in relation to specific applications.

Table 3-4  
Short-Term Storage Pad Dust Mitigation Analysis Summary  
(Cover Approaches)

Application: CCP Pile - Short-Term		Dust Mitigation Approach				
		Cover Approaches				
Characteristic	Soil Cover	Bottom Ash Cover	Straw Cover	Water and Lime Solution	Polymer Emulsion	Geosynthetic Fabrics
<b>1 General Performance Characteristics</b>						
- Fugitive Dust Control	GOOD	FAIR	FAIR	AVERAGE	EXCELLENT	GOOD
<b>2 Initial Application Requirements</b>						
- Construction Requirements	AVERAGE	AVERAGE	AVERAGE	EXCELLENT	AVERAGE	FAIR
- Material Availability	EXCELLENT	EXCELLENT	GOOD	GOOD	POOR	FAIR
- Labor Requirements	AVERAGE	AVERAGE	AVERAGE	GOOD	POOR	AVERAGE
<b>3 Capital Costs (per acre)</b>	\$4,030	\$0	\$300 - \$3,000	\$560	\$500 - \$3000	\$6,000 - \$9,000
<b>4 Operation and Maintenance Requirements</b>						
- Duration of Application	AVERAGE	AVERAGE	FAIR	AVERAGE	EXCELLENT	EXCELLENT
- Complexity of Application	AVERAGE	AVERAGE	GOOD	GOOD	AVERAGE	GOOD
<b>5 Integrity in Extreme Weather</b>						
- Freezing Temperatures	GOOD	GOOD	FAIR	AVERAGE	GOOD	GOOD
- High Winds	AVERAGE	POOR	POOR	AVERAGE	EXCELLENT	GOOD
- Drought (Dry and Hot)	AVERAGE	FAIR	FAIR	FAIR	EXCELLENT	GOOD
- Excessive Precipitation	FAIR	FAIR	FAIR	FAIR	EXCELLENT	GOOD
<b>6 Secondary Effects</b>						
- Reuse of On-Site Materials	EXCELLENT	EXCELLENT	POOR	FAIR	POOR	POOR
- Leachate Generation	AVERAGE	AVERAGE	FAIR	AVERAGE	EXCELLENT	GOOD
- Impact to Design	AVERAGE	AVERAGE	GOOD	EXCELLENT	EXCELLENT	GOOD
- Erosion	POOR	POOR	FAIR	AVERAGE	EXCELLENT	GOOD

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Short-term storage pad cover approaches do not include:

- Vegetated Soil Covers
- Erosion Control Matting

Table 3-5  
Short-Term Storage Pad Dust Mitigation Analysis Summary  
(Operational Approaches)

Application: CCP Pile - Short-Term		Dust Mitigation Approach				
		Operational Approaches				
Characteristic		Water Spray	Brine Spray	Wastewater Spray	Surfactants	Increasing Moisture Content
<b>1 General Performance Characteristics</b>						
- Fugitive Dust Control		FAIR	FAIR	FAIR	FAIR	FAIR
<b>2 Initial Application Requirements</b>						
- Construction Requirements		EXCELLENT	EXCELLENT	GOOD	EXCELLENT	EXCELLENT
- Material Availability		EXCELLENT	GOOD	EXCELLENT	AVERAGE	EXCELLENT
- Labor Requirements		EXCELLENT	GOOD	EXCELLENT	GOOD	EXCELLENT
<b>3 Capital Costs (per acre)</b>		\$0	\$100	\$0	\$100	\$0
<b>4 Operation and Maintenance Requirements</b>						
- Duration of Application		POOR	FAIR	FAIR	FAIR	POOR
- Complexity of Application		EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
<b>5 Integrity in Extreme Weather</b>						
- Freezing Temperatures		POOR	POOR	POOR	POOR	POOR
- High Winds		POOR	POOR	POOR	POOR	POOR
- Drought (Dry and Hot)		POOR	POOR	POOR	POOR	POOR
- Excessive Precipitation		POOR	POOR	POOR	POOR	POOR
<b>6 Secondary Effects</b>						
- Reuse of On-Site Materials		AVERAGE	POOR	EXCELLENT	POOR	POOR
- Leachate Generation		POOR	POOR	POOR	POOR	POOR
- Impact to Design		EXCELLENT	EXCELLENT	FAIR	GOOD	EXCELLENT
- Erosion		POOR	POOR	POOR	POOR	POOR

LEGEND	
EXCELLENT	EXCELLENT
GOOD	GOOD
AVERAGE	AVERAGE
FAIR	FAIR
POOR	POOR

Short-term storage pad operational approaches do not include:

- Working Face Minimization

Table 3-6  
Short-Term Storage Pad Dust Mitigation Analysis Summary  
(Physical Barriers)

Application: CCP Pile - Short-Term		Dust Mitigation Approach			
		Physical Barriers			
Characteristic		Dust Screens	Roofed Structure	Silo	Natural Barrier
<b>1 General Performance Characteristics</b>					
- Fugitive Dust Control		POOR	EXCELLENT	EXCELLENT	POOR
<b>2 Initial Application Requirements</b>					
- Construction Requirements		POOR	POOR	POOR	POOR
- Material Availability		POOR	POOR	POOR	POOR
- Labor Requirements		POOR	POOR	POOR	POOR
<b>3 Capital Costs (per structure)</b>		\$525,000	\$1.5M - \$2.5M	\$300K - \$500K	\$25,200
<b>4 Operation and Maintenance Requirements</b>					
- Duration of Application		EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
- Complexity of Application		POOR	POOR	POOR	POOR
<b>5 Integrity in Extreme Weather</b>					
- Freezing Temperatures		EXCELLENT	EXCELLENT	EXCELLENT	GOOD
- High Winds		GOOD	EXCELLENT	EXCELLENT	GOOD
- Drought (Dry and Hot)		EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
- Excessive Precipitation		EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
<b>6 Secondary Effects</b>					
- Reuse of On-Site Materials		POOR	POOR	POOR	POOR
- Leachate Generation		POOR	EXCELLENT	EXCELLENT	POOR
- Impact to Design		FAIR	POOR	POOR	FAIR
- Erosion		EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Table 3-7  
Short-Term Landfill Dust Mitigation Analysis Summary  
(Cover Approaches)

Application: CCP Landfill - Short-Term		Dust Mitigation Approach				
		Cover Approaches				
Characteristic	Soil Cover	Bottom Ash Cover	Straw Cover	Water and Lime Solution	Polymer Emulsion	Geosynthetic Fabrics
<b>1 General Performance Characteristics</b>						
- Fugitive Dust Control	GOOD	FAIR	FAIR	AVERAGE	EXCELLENT	GOOD
<b>2 Initial Application Requirements</b>						
- Construction Requirements	AVERAGE	AVERAGE	AVERAGE	EXCELLENT	AVERAGE	FAIR
- Material Availability	EXCELLENT	EXCELLENT	GOOD	GOOD	POOR	FAIR
- Labor Requirements	AVERAGE	AVERAGE	AVERAGE	GOOD	POOR	AVERAGE
<b>5 Capital Costs (per acre)</b>						
	\$4,030	\$0	\$300 - \$3,000	\$560	\$500 - \$3000	\$6,000 - \$9,000
<b>3 Operation and Maintenance Requirements</b>						
- Duration of Application	AVERAGE	AVERAGE	FAIR	AVERAGE	EXCELLENT	EXCELLENT
- Complexity of Application	AVERAGE	AVERAGE	GOOD	GOOD	AVERAGE	GOOD
<b>4 Integrity in Extreme Weather</b>						
- Freezing Temperatures	GOOD	GOOD	FAIR	AVERAGE	GOOD	GOOD
- High Winds	AVERAGE	POOR	POOR	AVERAGE	EXCELLENT	GOOD
- Drought (Dry and Hot)	AVERAGE	FAIR	FAIR	FAIR	EXCELLENT	GOOD
- Excessive Precipitation	FAIR	FAIR	FAIR	FAIR	EXCELLENT	GOOD
<b>6 Secondary Effects</b>						
- Reuse of On-Site Materials	EXCELLENT	EXCELLENT	POOR	FAIR	POOR	POOR
- Leachate Generation	AVERAGE	AVERAGE	FAIR	AVERAGE	EXCELLENT	GOOD
- Impact to Design	AVERAGE	AVERAGE	GOOD	EXCELLENT	EXCELLENT	GOOD
- Erosion	POOR	POOR	FAIR	AVERAGE	EXCELLENT	GOOD

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Short-term landfill cover approaches do not include:

- Vegetated Soil Covers
- Erosion Control Matting

Table 3-8  
Short-Term Landfill Dust Mitigation Analysis Summary  
(Operational Approaches)

Application: CCP Landfill - Short-Term		Dust Mitigation Approach				
Characteristic	Water Spray	Brine Spray	Wastewater Spray	Surfactants	Working Face Minimization	Increasing Moisture Content
<b>1 General Performance Characteristics</b>						
- Fugitive Dust Control	FAIR	FAIR	FAIR	FAIR	AVERAGE	FAIR
<b>2 Initial Application Requirements</b>						
- Construction Requirements	EXCELLENT	EXCELLENT	GOOD	EXCELLENT	FAIR	EXCELLENT
- Material Availability	EXCELLENT	GOOD	EXCELLENT	AVERAGE	EXCELLENT	EXCELLENT
- Labor Requirements	EXCELLENT	GOOD	EXCELLENT	GOOD	AVERAGE	EXCELLENT
<b>5 Capital Costs (per acre)</b>						
	\$0	\$100	\$0	\$100	\$0	\$0
<b>3 Operation and Maintenance Requirements</b>						
- Duration of Application	POOR	FAIR	FAIR	FAIR	POOR	POOR
- Complexity of Application	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT	AVERAGE	EXCELLENT
<b>4 Integrity in Extreme Weather</b>						
- Freezing Temperatures	POOR	POOR	POOR	POOR	AVERAGE	POOR
- High Winds	POOR	POOR	POOR	POOR	FAIR	POOR
- Drought (Dry and Hot)	POOR	POOR	POOR	POOR	GOOD	POOR
- Excessive Precipitation	POOR	POOR	POOR	POOR	FAIR	POOR
<b>6 Secondary Effects</b>						
- Reuse of On-Site Materials	AVERAGE	POOR	EXCELLENT	POOR	EXCELLENT	POOR
- Leachate Generation	POOR	POOR	POOR	POOR	AVERAGE	POOR
- Impact to Design	EXCELLENT	EXCELLENT	FAIR	GOOD	POOR	EXCELLENT
- Erosion	POOR	POOR	POOR	POOR	AVERAGE	POOR

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Table 3-9  
Short-Term Landfill Dust Mitigation Approach Summary  
(Physical Barriers)

Application: CCP Landfill - Short-Term		Dust Mitigation Approach	
		Physical Barriers	
Characteristic		Dust Screens	Natural Barrier
<b>1</b>	<b>General Performance Characteristics</b>		
	- Fugitive Dust Control	POOR	POOR
<b>2</b>	<b>Initial Application Requirements</b>		
	- Construction Requirements	POOR	POOR
	- Material Availability	POOR	POOR
	- Labor Requirements	POOR	POOR
<b>5</b>	<b>Capital Costs (per structure)</b>	\$525,000	\$25,200
<b>3</b>	<b>Operation and Maintenance Requirements</b>		
	- Duration of Application	EXCELLENT	EXCELLENT
	- Complexity of Application	POOR	POOR
<b>4</b>	<b>Integrity in Extreme Weather</b>		
	- Freezing Temperatures	EXCELLENT	GOOD
	- High Winds	GOOD	GOOD
	- Drought (Dry and Hot)	EXCELLENT	EXCELLENT
	- Excessive Precipitation	EXCELLENT	EXCELLENT
<b>6</b>	<b>Secondary Effects</b>		
	- Reuse of On-Site Materials	POOR	POOR
	- Leachate Generation	POOR	POOR
	- Impact to Design	FAIR	FAIR
	- Erosion	EXCELLENT	EXCELLENT

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Short-term landfill cover approaches do not include:

- Silos
- Roofed structures

Table 3-10  
 Long-Term Landfill Dust Mitigation Analysis Summary  
 (Cover Approaches)

Application: CCP Landfill - Long-Term		Dust Mitigation Approach						
		Cover Approaches						
Characteristic	Soil Cover	Vegetated Soil Cover	Direct Seeding	Water and Lime Solution	Polymer Emulsion	Erosion Control Mats	Geosynthetic Fabrics	
<b>1 General Performance Characteristics</b>								
- Fugitive Dust Control	GOOD	EXCELLENT	GOOD	AVERAGE	EXCELLENT	AVERAGE	GOOD	
<b>2 Initial Application Requirements</b>								
- Construction Requirements	AVERAGE	FAIR	AVERAGE	EXCELLENT	AVERAGE	AVERAGE	FAIR	
- Material Availability	EXCELLENT	GOOD	POOR	AVERAGE	POOR	POOR	POOR	
- Labor Requirements	GOOD	FAIR	POOR	EXCELLENT	POOR	FAIR	FAIR	
<b>5 Capital Costs (per acre)</b>	\$4,030	\$4430 - \$6530	\$300 - \$4000	\$560	\$500 - \$3000	\$4,000 - \$7,000	\$6,000 - \$9,000	
<b>3 Operation and Maintenance Requirements</b>								
- Duration of Application	AVERAGE	EXCELLENT	EXCELLENT	AVERAGE	EXCELLENT	AVERAGE	EXCELLENT	
- Complexity of Application	FAIR	POOR	FAIR	GOOD	AVERAGE	FAIR	FAIR	
<b>4 Integrity in Extreme Weather</b>								
- Freezing Temperatures	GOOD	EXCELLENT	EXCELLENT	AVERAGE	GOOD	AVERAGE	GOOD	
- High Winds	AVERAGE	EXCELLENT	EXCELLENT	AVERAGE	EXCELLENT	AVERAGE	GOOD	
- Drought (Dry and Hot)	AVERAGE	AVERAGE	AVERAGE	FAIR	EXCELLENT	AVERAGE	GOOD	
- Excessive Precipitation	FAIR	EXCELLENT	GOOD	FAIR	EXCELLENT	AVERAGE	GOOD	
<b>6 Secondary Effects</b>								
- Reuse of On-Site Materials	EXCELLENT	AVERAGE	POOR	FAIR	POOR	POOR	POOR	
- Leachate Generation	AVERAGE	GOOD	GOOD	AVERAGE	EXCELLENT	FAIR	GOOD	
- Impact to Design	AVERAGE	AVERAGE	GOOD	EXCELLENT	EXCELLENT	AVERAGE	GOOD	
- Erosion	POOR	EXCELLENT	GOOD	AVERAGE	EXCELLENT	AVERAGE	GOOD	

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Long-term landfill cover approaches do not include:

- Bottom Ash Covers

Table 3-11  
 Long-Term Landfill Dust Mitigation Analysis Summary  
 (Operational Approaches)

Application: CCP Landfill - Long-Term		Dust Mitigation Approach
		Operational Approaches
Characteristic	Working Face Minimization	
<b>1 General Performance Characteristics</b>		
- Fugitive Dust Control	AVERAGE	
<b>2 Initial Application Requirements</b>		
- Construction Requirements	FAIR	
- Material Availability	EXCELLENT	
- Labor Requirements	AVERAGE	
<b>5 Capital Costs (per acre)</b>	\$0	
<b>3 Operation and Maintenance Requirements</b>		
- Duration of Application	POOR	
- Complexity of Application	AVERAGE	
<b>4 Integrity in Extreme Weather</b>		
- Freezing Temperatures	AVERAGE	
- High Winds	FAIR	
- Drought (Dry and Hot)	GOOD	
- Excessive Precipitation	FAIR	
<b>6 Secondary Effects</b>		
- Reuse of On-Site Materials	EXCELLENT	
- Leachate Generation	AVERAGE	
- Impact to Design	POOR	
- Erosion	AVERAGE	

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Long-term landfill operational approaches do not include:

- Water spray
- Brine spray
- Wastewater spray
- Surfactants

Table 3-12  
 Long-Term Landfill Dust Mitigation Analysis Summary  
 (Physical Barriers)

Application: CCP Landfill - Long-Term		Dust Mitigation Approach	
		Physical Barriers	
	Characteristic	Dust Screens	Natural Barrier
<b>1</b>	<b>General Performance Characteristics</b>		
	- Fugitive Dust Control	POOR	POOR
<b>2</b>	<b>Initial Application Requirements</b>		
	- Construction Requirements	POOR	POOR
	- Material Availability	POOR	POOR
	- Labor Requirements	POOR	POOR
<b>5</b>	<b>Capital Costs (per structure)</b>	\$525,000	\$25,200
<b>3</b>	<b>Operation and Maintenance Requirements</b>		
	- Duration of Application	EXCELLENT	EXCELLENT
	- Complexity of Application	POOR	POOR
<b>4</b>	<b>Integrity in Extreme Weather</b>		
	- Freezing Temperatures	EXCELLENT	GOOD
	- High Winds	GOOD	GOOD
	- Drought (Dry and Hot)	EXCELLENT	EXCELLENT
	- Excessive Precipitation	EXCELLENT	EXCELLENT
<b>6</b>	<b>Secondary Effects</b>		
	- Reuse of On-Site Materials	POOR	POOR
	- Leachate Generation	POOR	POOR
	- Impact to Design	FAIR	FAIR
	- Erosion	EXCELLENT	EXCELLENT

LEGEND	
	EXCELLENT
	GOOD
	AVERAGE
	FAIR
	POOR

Long-term landfill physical barriers do not include:

- Silos
- Roofed structures

## **Wet Storage**

In addition to the dust mitigation approaches presented in this section for dry storage, CCP materials are also stored wet in ponds or impoundments. Wet storage of CCPs in an active or temporarily shut down (due to operations) impoundment is effective in keeping dust generation to a minimum.

Under normal conditions, the wet (submerged) portion of a storage pond or impoundment does not allow fugitive dust generation at the site. Any facility with exposed areas of CCPs (portions of the site not under water) has the potential for fugitive dust generation under certain weather conditions, such as high winds. Exposed areas may result from formation of CCP deltas as the facility fills, or lowering of the water level due to reduced inflows. These areas require regular operation and maintenance in order to manage dust generation. In general, dust mitigation for exposed areas at ponds is the same as those at dry facilities, although there are additional considerations associated with equipment access to the wet areas. One method unique to ponds is controlling the water level in the pond, as described below.

In some cases, depending on the volume of CCPs and the design of the pond, the water level can be raised to re-submerge exposed areas. While conceptually simple, this is not always easily done due to capacity and space limitations. Operational adjustments to facility valves, inlet control, and outlet control are required to accommodate the addition of water to the pond. There is also potentially the need for significant construction activities involving excavation, earth moving, and slope modifications for additional wet storage area, depending upon the existing site design. It is also noted that storage impoundments may be subject to state and federal dam safety regulations, which may specify geotechnical and hydraulic engineering limitation.

## **Mixing and Stabilization**

Another approach that is related to the operational approaches presented includes the mixing of FGD materials, fly ash, and lime. This is normally performed to obtain better handling of the CCP materials and stabilization of the CCP surface upon compaction at the storage facility as well as other plant operational considerations. Since a new type of CCP material (that is not prone to dusting) is developed through this process, mixing and stabilization was not included with the other operational dust mitigation approaches. This method presents only long-term solutions for CCP dust mitigation at landfills since this type of material sets and hardens within a short period of time. In addition, the expenses involved in purchasing a pug mill for mixing are not economical for short-term applications and the decision to implement this operation is often governed by other plant operation factors.

Partially dewatered calcium sulfite FGD material from inhibited oxidation systems is often mixed with fly ash and lime to produce a stabilized mixture for handling and placement in a landfill or structural fill. These materials together create a low strength cementitious material that binds together, creating a crusted

surface upon compaction that makes it less susceptible to wind and erosion. Calcium sulfate from a forced oxidation system can be more easily dewatered and does not need to be stabilized for handling purposes.

FGD material and fly ash, either together or separately, can be mixed with lime (typically using a pug mill) to obtain the positive dust suppression characteristics. The introduction of lime creates the cementitious nature of the material with Class F fly ash. Class C fly ash is self-cementitious and generally does not require the same quantity of lime in the mixture. Powder River Basin coal, being a younger sub-bituminous coal, typically produces a Class C fly ash that contains more than 20% lime (CaO) and exhibits pozzolanic and self-cementing properties. Powder River Basin coal supplies almost half of the coal used in the United States. In the presence of water, a Class C fly ash tends to gain strength and harden over time. Class C fly ash, either alone or mixed with FGD materials, has positive effects in terms of the hardening and encrustation of the CCP surface when mixed with water. Class F fly ash, either alone or mixed with FGD materials, is not self-cementing and generally requires addition of lime in order to encrust and harden. FGD materials can vary in characteristics, based upon the specific FGD system, operations, and dewatering at the power plant. FGD gypsum, although not self-cementing, has a natural tendency to encrust at the surface slightly following compaction; however, it still allows for stormwater percolating through the surface. It should be noted that the addition of lime to the mixture can take up to 3% of the landfill volume and should be monitored appropriately.

A benefit with mixing and stabilization is the potential for immobilizing the metals in the CCP matrix. Mixing FGD material with fly ash and lime decreases the amount of exposed fine particulate fly ash at the surface, which also naturally produces minor crusting at the surface. Once the surface is crusted, care should be taken by operations staff to not break, drive on, or otherwise disturb the material. Breaking the crust creates powdery material with little moisture or available unreacted lime to continue the fixation reactions. While the goal of mixing and stabilization is often geared toward other operational benefits, an ancillary outcome is a crusted or solidified surface, providing protection against wind and erosion.

The mixing and stabilization approach presents only long-term solutions for CCP dust mitigation at landfills because this type of material sets and hardens within a period of 3-4 days, which would require a utility to break up this concrete-like pile prior to moving or final storage. In addition, the expenses involved in purchasing a pug mill and the associated appurtenances for mixing are not economical for short-term applications.



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