Working Toward Zero Leachate Discharge for CCR Landfills

Glenn R. Leo¹
Michelle Spruth²

¹ Foth Infrastructure & Environment, LLC, 390 South Woods Mill Road, Suite 325, Chesterfield, MO 63017
² Foth Infrastructure & Environment, LLC, 800 Roosevelt Road, Building E, Suite 412, Glen Ellyn, IL 60137

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ABSTRACT:

Owners of Coal-fired generation facilities are challenged with managing effluent discharge from Coal Combustion Residuals (CCR) Landfills. Overcoming these challenges, requires engineering and technical solutions to provide a holistic approach for both the short and long-term life of the CCR Landfill. Foth Infrastructure & Environment (Foth) has technical expertise in the design of zero leachate discharge systems for CCR landfills and will present the drivers, benefits, analysis methods, modeling and design considerations for zero leachate discharge for lined CCR landfills. This approach will be applicable to most CCR landfills and provides a new methodology for consideration in CCR landfill design.

This presentation will provide a review of suggested inputs and subsequent outputs to account for in the design of a zero leachate discharge system and the importance of calibration and sensitivity analysis for modeling parameters.
INTRODUCTION

Foth (http://www.foth.com/) is an employee-owned company celebrating more than 80 years of client success through our Infrastructure, Environment, and Production Solution service-delivery teams. With 27 offices coast to coast, Foth can efficiently bring the knowledge and experience our clients need for their specific projects.

We have a dedicated Utilities group, within our Environment Division, focused on providing engineering and technical value-added solutions for generation and transmission clients.

This paper outlines the drivers, methodology, design and modeling concepts, and sensitivity analysis for assessment of zero leachate discharge management systems for CCR landfills.

ZERO LEACHATE DISCHARGE DRIVERS

As surface impoundments close and facilities convert to dry ash handling resulting in on-site CCR disposal at composite lined landfills, planning for long-term costs and regulatory risks with management of CCR leachate is critical for the operational and management plans for the site.

As part of planning, site modifications for management of CCR leachate should be considered at the design stage, to help reduce the associated long-term operation and maintenance costs included with off-site leachate treatment and potential risk of associated current and/or future regulatory requirements for effluent discharge.

METHODOLOGY FOR THE DESIGN PROCESS FOR ZERO LEACHATE DISCHARGE

The design process for a CCR landfill zero leachate discharge system needs to ensure that:

\[ \text{Inputs} - \text{Outputs} = \text{Zero} \]

This outcome requires identification, assessment and modeling of all liquid inputs and outputs to determine the overall water balance. Inputs typically include climatic data for precipitation, CCR material characteristics, and geometry of the waste area and leachate lagoon. Outputs typically include climatic data for evaporation, assessment of storm water runoff, determination of water-holding capacity of the CCR, and determination of available engineered outputs.

Site specific data is preferred for modeling; however, where site-specific data is not available, published or test data may be used. The modeling methodology requires analysis of known data to predict the volume of leachate generation over time. Other engineered outputs (i.e. evaporation) can also be applied to meet the goal of zero leachate discharge.
DESIGN AND MODELING CONCEPTS

Prior to design, it is important to have a clear understanding of site operations and constraints so as operational considerations can be incorporated into site design. This generally includes the volume of CCR waste for disposal, landfill phasing, cell geometry to determine open areas versus capped areas and slopes, and geometry of the leachate lagoon. Zero leachate discharge design should be incorporated into the overall Master Plan of the landfill. Variations in ash properties, placement and operational constraints over the life of the landfill will need to be factored into any model.

Identification of Modeling Inputs

Precipitation and CCR waste generation volumes vary over the life of a CCR landfill. It is important to incorporate material properties of the CCR for disposal and any variation in CCR deposited as well as seasonal variation of precipitation into the model. Additionally, waste placement over time and cell geometry are also incorporated into the modelling parameters.

Climatic data for precipitation is the most critical input for modeling to predict leachate generation, and should be site-specific data and/or published local data, if possible. In the absence of this data, the National Oceanic and Atmospheric Administration (NOAA) Climate Data can serve as a substitute. The engineer/scientist should incorporate any temporal variations and annual high precipitation values.

Modeling inputs of the material properties of CCR is necessary. Site-specific testing of the CCR waste provides the understanding of permeability, and in-situ moisture content and density relationship. This information provides a critical understanding of the storm water runoff/ infiltration relationship. Alternatively, if site-specific testing is not feasible, and if historical CCR material properties are not available published data may be used.

The timing of waste placement and the geometry of the leachate lagoon and waste area are important factors in design; cell size and percent slope from capped and uncapped areas throughout the life of the landfill are critical to accurately predicting leachate generation. Existing and historical survey information are helpful in providing detail on percent slope and capped versus uncapped areas.

Identification of Modeling Outputs

The modeling inputs identified are assessed using a volumetric approach to determine the predicted volume of leachate generated. The outputs of the model include runoff from direct precipitation to capped and uncapped areas, evaporation from direct precipitation to capped and uncapped areas, natural evaporation from the leachate lagoon, and absorption of precipitation by in-place CCR.
Runoff from direct precipitation to capped and uncapped areas can be calculated using a variety of methods (e.g. TR-55, rational method, MODFLOW, Hydrologic Evaluation of Landfill Performance [HELP] Model, etc.) and is incorporated into the model.

Evaporation from direct precipitation from capped and uncapped areas is not an easy variable to define. The engineer/scientist may consider a conservative estimate of 2 – 4% evaporation from uncapped areas. Evaporation from capped areas is addressed by combining the outputs from evaporation, runoff, and estimated leakage from capped areas based on the site-specific cap design for the landfill.

Natural evaporation from the leachate lagoon may be estimated using published data, such as NOAA Technical Report NWS 33 or can be calculated using the Penman equation. Pan evaporation data can also be used to estimate evaporation, but the engineer/ scientist should be aware that pan evaporation data and free water surface evaporation may not correlate.

The material property modeling inputs of CCR used to obtain an understanding of the storm water runoff / infiltration relationship are also used to calculate the water-holding capacity of the CCR. The volume of direct precipitation absorbed by the CCR material matrix is a volumetric output, and is only applied to the initial waste placement. Site-specific testing is preferred to determine the CCR material properties. If site-specific data is not available, published data may also be used. Typical values of the water holding capacity for some CCR may range from 20 to 40 gallons per cubic yard (gal/yd³) (99 to 198 L/m³).

The aforementioned evaluation is performed to determine the predicted leachate generation over time, which is the volume of leachate to be managed through engineered outputs to reach zero leachate discharge. Engineered outputs are often in the form of evaporation, but other site-specific mechanisms may also be applied.

SENSITIVITY ANALYSIS

Following assessment and modeling of site inputs and outputs, sensitivity analyses are undertaken to confirm and refine results. Details of ash placement over the life of the landfill is important in developing the model and sensitivity analysis for the site. Sensitivity analysis should be conducted through input changes such as variations in climatic data, calculations of runoff and evaporations, areas capped, areas uncapped, increased/decreased percent side slope, size of leachate lagoon, and amount of CCR placed and absorptive capacity.

Calculations for runoff and evaporation dominate the prediction of leachate generation in the volumetric model. Thus, particular attention should be given to these calculations and the supporting inputs during the sensitivity analysis. The sensitivity analysis should not include the engineered outputs, as these are applied to leachate management not leachate generation.
CONCLUSION

The modeling approach toward zero leachate discharge is an iterative process. Beyond the known model inputs, the engineer/scientist will need to consider the geometry of the landfill and/or leachate lagoon, optimization of landfill phasing, collaborative approaches to landfill operations, and thoughtful engineered outputs. Model outputs and future operational requirements will influence the landfill design.

Overcoming challenges of working toward zero leachate discharge for CCR landfills requires engineering and technical solutions to provide a holistic approach for both the short and long-term life of the CCR Landfill. Flexibility should be incorporated into the design to allow for future modifications due to additional and/or reduced leachate generation. Engineers/scientists should regularly calibrate models to site-specific data over time to validate inputs and outputs.

REFERENCES