# **Effective Remedial Measure**: Evaluating Monitored Natural Attenuation Paired with Source Control

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**ABSTRACT**

Monitored natural attenuation (MNA) coupled with source control is a viable component of remedial technologies evaluated under an assessment of corrective measures for coal combustion products (CCP) units demonstrating the detection of one or more Appendix IV constituents at statistically significant levels (SSLs) greater than groundwater protection standards (GWPSs) downgradient of the waste boundary. To demonstrate the effectiveness of source control coupled with MNA, groundwater data from four CCR units closed through source control (decanting/dewatering) and removal (excavation) were evaluated under pre-excavated and post-excavated conditions. The evaluation included examination of concentration trends associated with Appendix IV constituents and changes in groundwater geochemical conditions.

Each Appendix IV parameter exhibits a unique geochemical behavior related to the Site-specific constituent partition coefficient ($K_d$), response to changing geochemical parameters (*i.e.*, pH and Eh), and sorption capacity of the soil and/or rock matrix. Regarding constituent mobility of the Appendix IV parameters, the conservative, non-reactive constituents (*i.e.*, lithium) migrate in groundwater as soluble species and are not strongly attenuated by reactions with solids but are reduced in concentration with distance primarily by physical processes such as mixing (dispersion), dilution, and diffusion. Variably reactive constituents (*i.e.*, cobalt) can exhibit mobility depending on groundwater geochemical conditions and availability of sorption sites. Non-conservative, reactive constituents (*i.e.*, arsenic) tend to remain in mineral phase assemblages that are stable under variable Site conditions, demonstrating sorption as an effective attenuation mechanism. In addition, redox parameters [*i.e.*, dissolved oxygen, oxidation-reduction potential (ORP), and iron/manganese concentrations] are useful in understanding the changing geochemical conditions pertaining to oxidizing or reducing environments for chemical dissolution or sorption through co-precipitation and adsorption of constituents with precipitation of iron/manganese and aluminum oxides.

Empirical data from post-excavation case studies demonstrate the effectiveness of natural attenuation to reduce Appendix IV parameter concentrations, and in most cases, to less than GWPSs in a reasonable period of time after source control. Decreasing concentration trends may not be apparent prior to or during the early stages of source control. However, these case studies demonstrate how MNA can be effective after source control at locations where post-source-control data are not yet available. Monitoring and data evaluations after source control can be used to evaluate whether additional remedial measures in addition to MNA are needed. Conducting a preliminary MNA evaluation after source control will reduce the potential areas and constituents targeted for other remedial techniques if needed.