ENVIRONMENTAL PERFORMANCE OF CCPs

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Abstract

Large quantities of coal combustion products (CCPs) are produced in the United States by electric power plants. Coal is burned in conventional boilers as well as in fluidized bed combustion units; both of them produce fly ash, bottom ash (bed ash), and flue gas desulfurization (FGD) sludge. The American Coal Ash Association (ACAA) has developed annual statistics on the disposal and utilization of the CCPs nationwide. Approximately 30% of the generated CCPs is utilized and the remaining 70% is disposed in landfills and impoundments. More than 25 years of research, development, and monitoring efforts by many entities have produced a large body of knowledge on the characteristics and environmental performance of disposed and utilized CCPs.

In this paper, we provide a descriptive summary of the nature of impacts particularly on groundwater quality in the vicinity of the disposal and use facilities. Insights into the leaching, attenuation, and environmental fate of inorganic constituents of interest have been summarized.

Introduction

Coal combustion products (CCPs) are residues of coal burning in utility boilers and fluidized bed combustion units to produce electricity. Coal is a widely distributed fossil fuel available in the United States. More than 1.12 billion tons of coal are extracted annually from surface and deep mines in the United States (2001 data from U.S. Department of Energy). The vast majority of this annual production of coal is burned to produce electricity. Combustion of coal produces fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) sludge collectively named as CCPs. The American Coal Ash Association reported that in the year 2000 the U.S. electric utilities produced about 108 million tons of CCPs. About 30% of the CCPs is used in cement/concrete, structural fill, roadbase/subbase, snow and ice control, blasting grit, roofing granules, and in the wallboard production. Approximately 70% of the CCPs is land disposed in landfills and impoundments.

The land disposal of CCPs has been a subject of regulatory discussion at the Federal level under the Resource Conservation and Recovery Act (RCRA). In 1980, the Bevill amendment to RCRA exempted the fossil fuel combustion residues from the Subtitle C (hazardous waste) of RCRA pending the outcome of the U.S. EPA determination. RCRA required that the U.S. EPA conduct studies and determine if the fossil fuel combustion wastes should be regulated under Subtitle C of RCRA. The U.S. EPA studies and determination were to be based on the actual management practices for CCPs and the risks to human health and the environment from those management practices. In 1988, EPA submitted its first report to Congress and on August 9, 1993 made the first regulatory determination declaring that the disposal in landfills and surface impoundments of coal fly ash, bottom ash, boiler slag, and the FGD sludge did not require a Subtitle C regulation under RCRA. The U.S. EPA made its second regulatory determination on March 22, 2000, in which the Agency announced that national regulations under Subtitle D of RCRA would be developed to address the management of CCBs in surface impoundments and landfills. In addition, the Agency stated that regulations under Subtitle D of RCRA and/or possible modifications to existing regulations under SMCRA are warranted when CCPs are used to fill surface or underground mines. This second determination reaffirmed that the CCPs do not require to be regulated under the Subtitle C of RCRA.

As a result of national regulatory interest during the last 20 years, large amounts of effort were placed in developing characterization data, groundwater monitoring results, and risk assessments for the CCPs placed in landfills and impoundments. The Electric Power Research Institute (EPRI) developed a significant portion of the technical information that was relied upon by the U.S. EPA in making its regulatory determination. EPRI work emphasized studies on the leaching and attenuation chemistry of metals found in CCPs. EPRI studies also completed several field-scale monitoring and characterization studies of land disposal facilities where CCPs were placed by the power plants. This paper contains a summary of knowledge on leaching, attenuation, and fate of metals and soluble salts in the subsurface environment associated with landfills and impoundments used to manage CCPs.

CCP Composition and Environmental Performance Factors

Coal fly ash, bottom ash, and slag composition are dominated by aluminum and silica that are also the primary constituents of soils and geological materials. The FGD sludge composition is dominated by calcium and sulfur. All coal combustion products contain metals in trace amounts. The CCPs also contain significant amounts of calcium, magnesium, iron, and sulfur. Boron is a common constituent present in moderate amounts in the CCPs. The four types of CCPs vary in particle size and in their leaching potentials for the various chemical constituents contained in them. Therefore, the environmental performance factors are typically associated with pathways and receptors for the constituents of concern found in CCPs. RCRA regulates eight metals under its toxicity characteristic rule. These metals are barium, arsenic, selenium, chromium, cadmium, mercury, lead, and silver and they are present in CCPs in varying concentrations.

Other constituents in CCPs that provide an assessment of environmental performance include boron, sulfate, vanadium, nickel, zinc, molybdenum, and manganese. The groundwater pathway, where release and migration of constituents in CCPs disposed in landfills and impoundments would take place, is one of the major concerns of regulators in order to assess risks/impacts; therefore, attention has been placed on developing technical information on leaching of target chemicals. Similarly, studies have been completed to examine retardation or attenuation of metals in groundwater to understand the potential extent of migration of leached constituents. Results from both laboratory and field studies are available on the leaching and attenuation processes in reports and open literature papers.

Coal ash has the potential to produce leachates that contain measurable concentrations of chemicals of concern. Therefore, in the next subsection, a qualitative description is given to convey the nature of leaching and the impacts associated with leachate migration at CCP management facilities.

Observations Regarding Environmental Performance

Generally silica, aluminum, calcium, magnesium, and iron contained in the CCPs do not pose leaching and groundwater quality impact potentials at CCP containing landfills and impoundments. However, for the western coal ash where leachate pH can be highly alkaline (above pH 10), the aluminum concentrations in the leachates can be also quite high. The increased aluminum levels are reflective of the increased solubility of aluminum at high pH conditions.

Barium is one of the regulated RCRA metals and is also present in the CCPs. Leaching test results from numerous samples of CCPs covering a large number of power generating facilities indicate that barium in CCP leachates are below regulatory standards and that leachates from naturally occurring soils in the United States also contain comparable levels of barium in solution.

Mercury and silver are regulated RCRA metals but are present in CCPs in extremely low concentrations. Available laboratory and field-scale data strongly suggest that leaching and migration of these two metals contained in CCPs are not likely to occur. Therefore, mercury and silver in CCPs pose no risk to the environment from landfills and impoundments where the CCPs are disposed.

Cadmium is another regulated RCRA metal and is present in low concentrations in CCPs. Available laboratory and field measurements indicate that very low concentrations of cadmium can be found in leachates. However, the majority of the data indicates that the cadmium concentrations in the CCP leachates are well below all applicable regulatory standards on water quality.

Similar to mercury, silver, and cadmium, both lead and chromium seldom leach from CCPs and, therefore, do not migrate in the groundwater near CCP management facilities. Lead and chromium in CCPs are typically present in solid phase compounds that have very low dissolution and leaching potentials for the two metals. While these observations provide the most likely performance of these five metals in CCPs, there are some extreme situations (e.g., very acidic pH, very alkaline pH) where increased leaching for these metals can occur.

Arsenic is found in CCPs at low to somewhat high concentrations. Laboratory and field measurements have shown that leachates from CCPs can contain low to moderately high concentrations of arsenic. However, most of the arsenic is present as arsenic (V) species that is relatively low in toxicity compared to arsenic (III) species. Acidic to near neutral coal ashes generate leachates with arsenic concentrations ranging from 300 ug/L to about 800 ug/L. Occasionally the leached arsenic has resulted in localized increases in groundwater concentrations down gradient of the CCP disposal unit. However, available literature also indicates that arsenic has high attenuation potential thereby its potential to migrate in groundwater is greatly reduced. U.S. EPA in its regulatory determination in 2000 noted that there exists a potential for arsenic impacts on groundwater quality in the very long-term.

Selenium is another RCRA regulated metal. Low concentrations of selenium can leach from CCPs and can migrate short distances in groundwater. However, the leaching potential for selenium in CCPs is somewhat higher under alkaline conditions (i.e., when pH is greater than 10). The environmental chemistry of selenium is complex because selenium in CCPs is present in two valence states. The presence of both types of selenium species in the CCP leachates makes it difficult to predict the migration potentials. However, selenium does attenuate moderately well through adsorption onto soil/aquifer material.

Boron and molybdenum are relatively soluble constituents present in CCPs. Leachate concentrations for boron can range from under 1 mg/L to over 100 mg/L. Boron in leachate shows a very small potential for retardation/attenuation by soils/aquifer material. In the field and laboratory studies, boron has been found in elevated concentrations in groundwater at the CCP management sites. In fact, boron is often used as an indicator of leachate migration from landfills and impoundments used to manage CCPs.

Molybdenum is also a soluble constituent and leachate concentrations usually are below 2 mg/L. But molybdenum has been observed in elevated concentrations in groundwater at ash disposal as well as ash use sites.

Sulfur, commonly present as sulfate of calcium, magnesium, or sodium, is highly soluble and often is abundantly present in the CCPs. Field-scale studies and monitoring of groundwater have shown that sulfate concentrations in leachates and groundwater can be in the range of 200 to 2,500 mg/L. Similar to boron, sulfate is not subject to chemical attenuation and, therefore, is quite mobile in groundwater. Both boron and sulfate are, therefore, often times used as indicators of leachate migration from landfills and impoundments used to manage CCPs.

Metals such as nickel, vanadium, copper, and zinc are found in CCPs as well as in soils. Leaching tests do show some release of these constituents as a result of dissolution by the water contacting the CCPs. However, available monitoring data do not show migration and groundwater quality impacts associated with these constituents in CCPs.

At some CCP management facilities, manganese has shown increased concentrations in monitoring wells. Leaching tests show low to moderate potential for manganese release from CCPs at concentrations that can explain the observed increases in groundwater concentrations of manganese. Therefore, the relationship between CCP management facilities and elevated manganese concentration in down gradient groundwater is not clear.

The increasing use of NO_x control technologies at power plants is expected to result in increased concentration of ammonium in coal ash. Limited amounts of available data do indicate that leachate generated from the ammoniated ash will contain significant amounts of ammonium. Depending on the soil and aquifer conditions, the ammonium in leachate is likely to convert to nitrate that could migrate in groundwater without attenuation resulting in elevated concentrations of nitrate and/or ammonium in down gradient groundwater.

Summary and Conclusions

The foregoing description provides a qualitative summary of leaching and effects on groundwater for a number of metals and soluble salts contained in CCPs. No effort was made to present in this paper a quantitative summary of available data on the release and migration of constituents of concern to present the knowledge on the environmental performance of CCPs when disposed in landfills and impoundments.

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