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Imminent and substantial endangerment to human health and the environment from use of coal ash as fill material at construction sites in Puerto Rico: A case study

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Abstract

The focus of this paper is secondary, also referred to as beneficial use of coal combustion residuals (CCRs) in Puerto Rico. This paper discusses the disposal of CCRs in Puerto Rico, the imminent and substantial endangerment to human health and the environment it presents and the implications of CCR use worldwide. Virtually one hundred percent of the CCRs generated in Puerto Rico are used as fill material at residential, commercial and road construction projects, often in flood prone areas in the southeastern region of the island. The secondary use of approximately 300,000 tons of CCRs per year as fill material at construction sites above a sole source aquifer poses risks of imminent and substantial endangerment to human health and the environment. Analytical test results of the CCRs being used indicate high levels of constituents of concern and radioactive isotopes. We strongly urge barring use of CCRs as land fill and land application in light of proven and potential damage cases resulting from these practices. References in parentheses are to pages in the EPA Proposed Rule on Hazardous and Solid Waste Management System; Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals from Electric Utilities (proposed rule) and the Bevill Exemption.

Keywords: Aquifer; Ash; Coal; Combustion; Health

1. Introduction

Currently, it is estimated that approximately, 136 million tons of coal ash are generated in the United States. This enormous waste stream led to the creation of the Coal Combustion Product Partnership,

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known as C2 P2 between the coal combustion industry and the United States Environmental Protection Agency (EPA) to promote the alleged beneficial use of CCRs. EPA is currently re-evaluating the C2 P2 program on the basis of findings by the EPA Office of the Inspector General indicating that EPA did not perform adequate risk analysis of CCR use and proliferation of proven and potential damage cases resulting from CCR use.

In Puerto Rico, a single coal-fired power plant generates over 300,000 tons of CCRs per year. However, there are no CCR disposal facilities (*e.g.* landfills, impoundments) in Puerto Rico. Therefore, virtually all of the CCRs generated on the Island are disposed of under the guise of beneficial or secondary use. As in many jurisdictions, the Commonwealth of Puerto Rico does not regulate secondary use or disposal of CCRs. This dearth of regulation has created a situation in which virtually every ton of CCRs generated in Puerto Rico ends up as fill material at construction sites. Most of the new construction are commercial, residential and road projects, especially single-family housing on the southeast coast and in the expansion of the Salinas Municipal Landfill. The sole source of potable water for the residential and commercial projects in the Municipalities of Salinas and Santa Isabel is the South Coast Aquifer which supplies tens of thousands of residents of southeastern Puerto Rico. The urgency of this matter cannot be overestimated. CCR samples taken in Puerto Rico reflect high concentrations of heavy metals and radioisotopes. Furthermore, many of the CCRs are near ecologically sensitive areas, like wetlands and even a natural reserve. Proven and so called potential damage cases where heavy metals have been detected in groundwater around the United States, indicate that the secondary use of nearly 300,000 tons per year as fill material at construction sites above a sole source aquifer poses imminent and substantial endangerment to human health and the environment.

2. Methodology

This paper uses the case study method and is based on the secondary use of CCRs in Puerto Rico, samples of CCRs and review of pertinent literature.

3. Results and discussion

3.1. Secondary use of CCRs

In Puerto Rico, the Applied Energy Systems (AES) coal combustion plant disposes of approximately 300,000 tons of the coal ash it generates per year by virtually paying construction contractors to use the CCRs as fill material at residential, commercial and road construction sites. The AES coal combustion residuals are composed of fly ash and bottom ash. AES indicates that it mixes both coal residuals, adds water, dries and cuts the mixture that it then transports, free of charge to construction sites. Land filling or application of CCRs presents imminent and substantial endangerment to human health and the environment because of the highly variable nature and constituents of concern in the CCRs and high humidity levels in Puerto Rico's tropical climate. In the Continental United States, the characterization of CCRs, when done is frequently based on samples provided by the coal combustion industry rather than random sampling by independent professionals. Recent samples of CCRs from the AES coal combustion plant at a residential construction site in Salinas, Puerto Rico indicates alpha particles of 9.9 pCi/g, nearly twice the levels of CERCLA applicable or relevant and appropriate requirements (ARARs) for surface soil, in addition to 5.7 pCi/g of beta particles and high levels of arsenic and other metals.

The AES coal combustion plant in Puerto Rico does not have any on-site CCR landfill or impoundment. AES is not required to have a permit that would provide regulatory oversight to address the risk from existing stockpiling or land filling of CCRs. The AES coal plant frequently stockpiles tens

of thousands of tons of CCRs in proximity to the Jobos Bay. Particles of CCRs are mobilized by the Caribbean breeze into communities, farms, forests, coastal areas and water bodies.

The AES plant also lacks any off-site CCR disposal facility. The present disposal and utilization method is land filling at residential, commercial, including the Salinas Municipal Landfill and road construction sites primarily in southeastern Puerto Rico, over the South Coast Aquifer.

EPA exempted CCRs from regulation under the Resource Conservation and Recovery Act. The Bevill Exemption for CCRs is based on EPA's belief, in 1993 that, "human populations generally are not directly exposed to the groundwater in the vicinity of coal-fired utility waste management sites, public drinking water intakes are usually at least several kilometers from the sites" (58 FR 42468). That is not the case in Puerto Rico where CCRs are being disposed of directly above the South Coast Aquifer in residential, commercial and road construction projects in the vicinity of public supply water wells.

The Commonwealth of Puerto Rico does not regulate CCR disposal or use. AES often delivers the CCRs free of charge to construction sites. Contractors pay a nominal charge of .15 cents per ton of CCRs. Such use cannot appropriately be characterized as beneficial because large amounts of CCRs are being disposed of as fill material to raise and contour the construction sites often in flood prone areas. In some cases, construction projects are filled with CCRs below the aquifer water table. An AES document presented in 2005 where the company attempted to promote the use of CCRs in Asuncion, Paraguay at an engineering conference indicates that the CCRs are sensitive to humidity and contain heavy metals that vary in each CCR sample. The AES plant utilizes a fluidized bed combustion (FBC) boiler that removes sulfur through use of limestone. Thus, the AES CCRs presumably contain sulfur compounds and high amounts of alkalinity.

The management of CCRs poses human health and environmental problems. The available data in 1993 from coal combustion landfills and surface impoundments demonstrated the existence of potential human exposure to groundwater contamination because CCRs constituents were leaching in excess of primary Maximum Contaminant Levels (MCLs) (58 FR 42474). In 1993, the potential for human exposure to ground water contaminants from CCRs was allegedly limited because EPA found that, "only 29 percent of sites have any population within 1 kilometer and only 34 percent of sites have any drinking water system within 5 kilometers" (75 FR 42475). This is certainly not the case today, particularly in Puerto Rico. The high population density and reliance on groundwater augments human exposure to CCR contamination. Thus, since virtually all disposal of CCRs is in heavily populated areas, above the sole source Aquifer, contamination is likely to occur. Infiltration and transport of contaminants in groundwater may vary with site or regional factors such as depth of groundwater, hydraulic conductivity, soil type, net recharge and other factors. (75 FR 42475). It has been recognized that use of CCRs near water bodies with low flow rates such as swamps or marshes may cause local environmental damages (75 FR 42475). The vast majority of CCR disposal sites in Puerto Rico are located in close proximity just north of wetlands and mangrove forest systems such as the Jobos Bay National Estuarine Research Reserve, a National Oceanic and Atmospheric Administration (NOAA) designated resource that is home to the second largest extension of mangrove forest in Puerto Rico. EPA has long recognized that unlined disposal sites over shallow ground water with nearby wells pose risks to human health and the environment. (75 FR 42476). The alleged trend toward increased use of control measures such as liners, covers and ground water monitoring has thus far served to exempt CCR disposal from regulation (75 FR 42476). This reasoning does not apply in cases like Puerto Rico, where land disposal of all CCRs in the absence of liners and groundwater monitoring is the norm.

This situation has created a disproportionate burden on the people and environment of the poorest municipalities in Puerto Rico. Jurisdictions with weak regulatory frameworks and/or a history of lax environmental or subtitle D enforcement, such as Puerto Rico will not achieve safe handling of CCRs. The race to the bottom phenomenon posits that jurisdictions that seek to attract "low cost" energy generators or industries will forego environmental protection and regulation. The race to the bottom phenomenon is manifested in various ways, including lack of certain protective elements, failure to

impose the requirements for which they have authority and/or lax enforcement. In 2000, EPA had already identified "numerous situations" where controls were not being applied (65 FR 32231). Often, these jurisdictions lack the resources needed to monitor operations that entail potentially significant environmental impacts. This happens both in the United States and abroad. A case in point is the Dominican Republic, where AES CCRs were disposed of with no protective measures.

CCRs have been used to form a storm water retention pond for a residential construction project in proximity to an irrigation canal and the South Coast Aquifer with no liner or groundwater monitoring. The CCR samples taken at the site indicated that the alpha radioisotopes reached 9.9 pCi/gm nearly doubling the ARAR standard. When the beta test result of 5.4 pCi/g is added, exposure to radiation from AES-PR CCRs is three times the ARAR standard for surface soil. The CCRs are currently exposed to wind and water erosion because they were used to create a storm water retention pond for a residential project of approximately 500 homes.

In Puerto Rico, often excessive quantities of CCRs are being used to restructure construction sites in flood prone areas to raise ground elevations. There is reason to believe that even relatively small amounts of CCRs pose a significant risk to human health and the environment as is evident in the case of CCR contamination in the Dominican Republic. Relatively small amounts of CCRs contain large amounts of arsenic, other toxic metals and radioactive isotopes.

3.2. Background of CCR use in Puerto Rico

Currently, Puerto Rico does not have any type of regulation regarding secondary use of CCRs. There is no guidance regarding what could be considered a beneficial use, its conditions or limitations. There are no permit or notification requirements. Also, there is no independent characterization of the CCRs prior to secondary use. In addition, Puerto Rico does not regulate the practice of hydrology and there are no provisions for state registration of hydrologists. This issue is significant because of the particular importance of flooding and ground water contamination risks posed by CCR land filling or disposal.

In 1996, the Puerto Rico Environmental Quality Board (EQB) issued a resolution providing that the proposed AES coal combustion plant in Puerto Rico was not required to comply with the provisions applicable to installations that generate solid waste. AES argued to the EQB that one hundred percent (100%) of the CCRs generated at its plant would have an alleged 'beneficial use.' In the Resolution, EQB indicated that since its regulations define solid waste as materials that are disposed, discarded or abandoned[i], and AES had alleged that none of the CCRs would be discarded; CCRs were not subject to nonhazardous waste regulation. Local municipal authorities that previously favored use of CCRs as construction fill now reject its use within their respective jurisdictions. This form of haphazard regulation, based on personal observation and experiences related to CCR disposal, is not protective of human health and the environment because CCR generators and secondary users relocate to municipalities that are unaware of the risks posed by land filling with CCRs. The Puerto Rico Legislature is currently considering a bill that would lead to regulation of secondary use of coal ash.

In 2004, the Texas Transportation Institute at Texas A&M University issued a study entitled, *Physical, Mechanical and Chemical Evaluation of Manufactured Aggregate*, based on CCRs from the AES plant in Puerto Rico. The study indicated that all coal combustion by-products possess unique properties based on the composition of the coal ash and production processes. Throughout the study, the authors indicated the need for further research and that the AES CCRs, "should not be used as **a** pavement base of structural foundation until the chemical stability potential is satisfactorily addressed."

In March 2006, the University of Puerto Rico released a document entitled, *Possible Applications for Circulating Fluidized Bed Coal Combustion By-Products from the Guayama AES Power Plant*, prepared for AES Puerto Rico, LP. The information on the physical and chemical results of the CCRs was provided by AES to the authors of the document. The study stated that, "a detailed evaluation of physical, mineralogical and mechanical properties of AES fly ash is recommended in order to better

determine suitability of CCP (CCRs) for different applications". The document indicates the need for corrosivity testing of the CCRs, evaluation for expansion due to moisture, leachate composition studies, tests to determine organic impurities and elasticity index to determine compliance with AASHTO, checks for potential impact to groundwater and the possibility of presence of radioactive components, and potential wind and surface water erosion. Other tests recommended include determination of achievable compressive strengths, flowablility tests, corrosion potential in situations of high humidity, such as Puerto Rico's tropical environment. A detailed feasibility study, examination of the CCRs high abrasion potential, risk of saturation, disposal of ash loaded with pollutants were recommended. Testing with a field component taking into account potential degradation and strong alkaline characteristics and comprehensive characterization of AES CCRs was also recommended. The authors cited studies indicating the large variations in CCRs, moisture content, damage to plant transpiration and photosynthesis from CCRs, percolation to groundwater risks, susceptibility to collapse that increases with inundation stress such as rising water tables, elevated sulfur levels and swelling damage.

In spite of all the warnings, tests were not done and AES CCRs have been widely used as fill material primarily over the South Coast Aquifer. The Puerto Rico authorities have not required any of the tests mentioned prior to secondary use of CCRs.

3.3. Imminent and substantial endangerment to human health and the environment

Proven and potential damage cases such as Pines, Indiana that became a superfund site due to groundwater contamination from CCRs and the Battlefield Gulf Course in Chesapeake, Virginia, demonstrate the risk of using CCRs as fill material at construction sites and in landfills. Multiple studies indicate the risks posed by CCR land application and mine filling.

As anticipated by EPA in the May 2000 Regulatory Determination, arsenic in CCRs present a risk that cannot be ignored. The result of the Salinas CCR sample reflects an arsenic level of 23 mg/Kg. EPA identified potential human health risks from arsenic when CCRs are used for agricultural purposes as a lime substitute in 2000. The use of CCRs as fill material at construction sites in flood prone areas, nearby water bodies such as aquifers and irrigation canals raises similar concerns.

Contrary to the situation in 2000, when EPA had not identified any damage cases associated with beneficial use practices, the contaminations in Pines, Indiana, and the Battlefield Golf Course in Chesapeake, Virginia, among others (75 FR 32223) are a clear indication of the dangers of CCR land filling or application.

The potential danger to human health and the environment from disposal of CCRs at construction sites is the probability of leaching of heavy metals and radioactive isotopes into the soil and sole source public water supply aquifer. There is also potential danger of ingestion from fugitive dust generated by CCRs stockpiled at construction sites and at the AES coal combustion plant.

Samples of CCRs from a construction site in Salinas, Puerto Rico revealed the presence of 23 mg/kg of arsenic 720 mg/kg of barium, 140 mg/kg of boron, 310 mg/kg of manganese, 6500 mg/kg of magnesium, 19 mg/kg of selenium, 130 mg/kg of vanadium, among other elevated levels of metals. In addition, the sample of AES CCRs indicates gross alpha pCi/g of 9.9 and gross beta pCi/g of 5.727.

It is noteworthy that only 1294 pounds of CCRs are required to reach the reportable quantity for arsenic of one pound that contains 773 parts per million (75 FR 35185). Similarly, every 2,604 pounds of CCRs include the reportable quantity of one pound with 384 parts per million of mercury. The reportable quantity of ten pounds of cadmium with 760ppm is found in 13,158 pounds of CCRs (75 FR 35185)
Land filling of CCRs presents special risks in residential construction sites because of potential soil ingestion by children.

In 2000, EPA determined that CCR disposal in direct contact with groundwater potentially increases the release of hazardous metals (75 FR 32231). The land disposal of CCRs at construction sites in proximity to the South Coast Aquifer presents imminent and substantial endangerment of the public water

supply for tens of thousands of people.

The Battlefield Golf Course potential damage case is an example of the fact that presumably protective state provisions did not prevent contamination of an aquifer from CCR land filling. In spite of the fact that the Virginia Administrative Code required that the CCRs be placed at least two feet above the ground water level and be covered by an 18 inch soil cap, on-site wells were contaminated by CCRs and threaten to migrate off-site (75 FR 35231). A requirement that land fill or application of CCRs be placed two or more feet from the upper limit of the natural water table is not sufficiently protective of human health and the environment because it does not take into account rainy periods where aquifer water levels rise above the natural water table. CCR use should be totally prohibited in areas overlying aquifers, flood plains, wetlands and karst areas. There is evidence that heavy rainfall exacerbates CCR contamination. As was documented in the Emory River, elevated levels of arsenic, cadmium, chromium and lead were detected after heavy rainfall (75 FR 35233).

EPA acknowledges that, "management of CCRs in unlined or clay lined waste management units result in risks greater than the risk criteria of 10-5 for excess cancer risks to humans or a HQ (hazard quotient) greater than 1 for non-cancer effects to both human and ecological receptors." (75 FR 35144). The 90th percentile risk estimates for arsenic that leaks from clay-lined landfills are as high as 1 in 5000 individual lifetime excess cancer risk. (75 FR 35145) Unlined landfills pose risks for antimony, molybdenum and arsenic. The later pose risks as high as 1 in 2000 individual lifetime excess cancer risk. Clay lined fluidized bed combustion (FBC) landfills presented estimated 90^{th} percentile risks above criteria for arsenic and antimony (75 FR 35145). There is no reason to believe that land filling and application of FBC CCRs do not pose equal or greater risks.

EPA has recognized that "ingestion of groundwater with CCRs (according to the risk assessment) poses estimated trivalent arsenic cancer risk of 4 in 10,000 for unlined landfills and 2 in 10,000 for clay-lined landfills at the 90^{th} percentile (75 FR 35169). Unlined landfills pose risks of three times the reference dose for thallium and three times the reference dose for antimony at the 90^{th} percentile (35169-70). Unlined FBC waste landfills pose a three in 100,000 cancer risk for arsenic at the 90^{th} percentile (75 FR 35170).

EPA has been ordered to establish a Clean Air Mercury Rule (CAMR) by November 16, 2011. The rule will set mercury emissions standards for power plants under the hazardous air pollutant (HAPs) program of Clean Air Act §112. It is expected that an 80% reduction in mercury emissions at coal-powered plants will significantly increase the amounts of the pollutant collected in the control equipment and CCRs. Mercury is a highly toxic substance even in minimal quantities, which persists indefinitely in the food chain. Placing the mercury directly into the environment through secondary use of CCRs, such as filling in construction activities will create a public health hazard, especially when the filling occurs in areas above aquifers. Similarly, EPA has proposed other air pollution rules, such as the "Tailoring Rule" and the "Transport Rule" that could have effects on the composition and leaching capability of CCRs. The "Tailoring Rule" applies to green house gas (GHG) emissions from large facilities, including many of the coal-fired power plants, which benefit from the Bevill Exemption. Coal-fired power plants and any other large facilities that emit over 75,000 tons per year of GHGs will be subject to best available control technology (BACT) under this rule. It is still not clear what BACT will be for coal-fired power plants or its effects on CCRs. Carbon dioxide (CO2), one of the six GHGs regulated under the rule, is highly corrosive and will likely interact with the CCRs. EPA has also promulgated a "Transport Rule" to further regulate sulfur dioxide (SO2) and nitrogen oxide (NOx) emissions from electric utilities in 28 states. This rule will substitute the Clean Air Interstate Rule (CAIR) as a way to help noncompliant downwind states that receive air pollutants from upwind states to come into compliance with the National Ambient Air Quality Standards (NAAQS). Analysis is required to determine the effects of these chemicals on the composition and leaching capability of CCRs.

The issue of what amount of CCRs presents unacceptable risks to human health and the environment should be considered in conjunction with the fact that CCRs have been shown to leach metals with

significant variability (75 FR 35162) Thus, the 50,000 tons of AES CCRs disposed of in Arroyo Barril, Dominican Republic was sufficiently harmful that AES agreed to pay six million dollars to settle one in a series of lawsuits.

CCRs disposed of at residential and commercial construction sites over the South Coast Aquifer represent imminent and substantial risk of contamination to groundwater supplies in the vicinity of the sites. In every case where CCRs have been used in Salinas, Puerto Rico, the residential and commercial projects are served from the underlying groundwater in the same vicinity of CCR disposal. Puerto Rico's tropical climate, particularly heavy rain storms during hurricane season, is not compatible with the use of CCRs for structural fill even if compacted in layers and placed on a drainage layer.

The CCRs used at multiple construction sites in Puerto Rico have had adverse impacts on air quality as coal ash clouds have formed, because the CCRs are either not covered or covered with a thin layer of dirt that quickly erodes leaving the CCR particles to disperse in the air. EPA acknowledges that a fugitive dust screening assessment indicates that CCRs pose risks of exceeding National Ambient Air Quality Standards (75 FR 35145). In many construction sites where CCRs have been used, there is visible evidence of erosion of the thin layer of dirt placed above the CCRs. The Caribbean breezes mobilize the dirt and CCRs into the air, exposing residents to CCR particulate matter. As noted by EPA, the potential and extent of adverse health effects due to fugitive dust from CCR disposal has been demonstrated (75 FR 35215). EPA also notes that CCR dust can be carried over long distances and settle on ground or water. Effects can include alteration by CCRs of nutrient balance of coastal waters, depletion of soil nutrients, damage to ecosystems and farms. (75 FR 35215). An EPA draft study has determined that without fugitive dust controls, CCR landfills pose risks of exceeding NAAQS for fine particulate matter. (75 FR 35177) Photographs of residential construction sites where CCRs were used in Salinas, Puerto Rico, reflect virtual clouds of CCRs in spite of the fact that the Commonwealth government theoretically requires fugitive dust controls at construction sites. Although enforcement of such controls has never been good, the recent dismantling of permitting and environmental agencies has created a *laisse faire* situation.

These sites are often within one kilometer of marine ecosystems, such as mangrove forests, beaches and bays. In fact, the South Coast Aquifer is hydrologically connected to the bays and Nigua River. Various studies have documented deformities in wildlife due to CCR contamination of habitats (75 FR 35171).

There is also concern that there will be cumulative or synergistic effects of the metals and chemicals leaching from the landfill in conjunction with the large amounts of CCRs disposed of at construction sites. This situation seems similar to that of Pines, Indiana

As a result of the availability of CCRs for land filling in construction projects there has been a boom in construction of sprawling single-family dwellings over the South Coast Aquifer. Considering Puerto Rico's limited territorial dimensions, construction of single-family housing does not constitute low-impact, smart or sustainable development but rather contributes to urban sprawl and significant impacts to coastal ecologic systems. The vast majority of construction sites where AES CCRs are being disposed are located in proximity to the AES coal combustion plant in Guayama, Puerto Rico indicating concentration of contaminants.

4. Conclusion

CCRs generated in Puerto Rico are currently disposed of under the guise of beneficial use as fill material at construction sites, many of which are located in flood prone areas over the South Coast Aquifer. The main economic incentive for this type of land-based use of CCRs is the availability of CCRs facilitated as fill material that contractors are virtually paid to use, when transportation costs are covered by the AES coal combustion plant. Analytical test results of the CCRs being used indicate high levels of heavy metals such as arsenic, barium, boron and others and radioactive isotopes above CERCLA

applicable or relevant and appropriate requirements (ARARs) for surface soil. Land filling or application of CCRs presents imminent and substantial endangerment to human health and the environment because of the highly variable nature and constituents of concern in the CCRs, presence of aquifers and wetlands and high humidity levels in Puerto Rico's tropical climate. Proven and potential damage cases require barring land filling or land based applications of CCRs.

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