Memorandum

MIAMI-DADE COUNTY

Date: May 3, 2022

Agenda Item No. 8(M)(1)

To: Honorable Chairman Jose "Pepe" Diaz
and Members, Board of County Commissioners

From: Daniella Levine Cava
Mayor

Daniella Levine Cava

Subject: Resolution Authorizing the County Mayor or County Mayor's Designee to Extend the Ash Reuse Pilot Study Project and Continue the Agreement between the Department of Solid Waste Management and Covanta Dade Renewable Energy Ltd. to Process Ash to be Reused for Beneficial Purposes as a Material Substitute in the Production of Cement; Extend the Agreement by 12 Months Due to COVID-related Delays; and Provide a Report on the Study

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Executive Summary

On March 8, 2016, the Board of County Commissioners (the "Board") approved Resolution No. R-213-16, which authorized a 12-month research project agreement between the Department of Solid Waste Management ("DSWM") and the University of Florida ("UF") Department of Environmental Engineering Sciences, Engineering School of Sustainable Infrastructure and Environment and the Hinkley Center for Solid and Hazardous Waste Management. The purpose of the research project was to determine the suitability of ash from the County's Resources Recovery Facility ("RRF"), as a substitute for coal ash in the production of cement. On November 7, 2017, the Board subsequently approved Resolution No. R-1057-17 which authorized additional time and additional funds to the research project. The research project totaling $187,023 was completed in 2018 and determined conclusively that there was no increased direct exposure or leaching risk when the County's bottom ash was incorporated into cement production. Moreover, while there is a cost for the processing of the ash, the program will produce a net cost savings to the County by reducing the tonnage of ash that must be landfilled. A copy of the final report with the results of the research project dated August 2018 is attached (see Attachment 1) and was provided to the Florida Department of Environmental Protection ("FDEP") in January 2019.

On January 25, 2021, the County agreed to make a portion of the ash landfill at the RRF available to Covanta Dade Renewable Energy Ltd. ("Covanta"), for operation of a mobile metals processing unit for 1 year (the "Agreement") (see Attachment 4). This item will allow DSWM to extend the Ash Reuse Pilot Study Project and continue the Agreement with Covanta to process ash to be reused for beneficial purposes as a material substitute in the production of cement and extend the Agreement by 12 months because of COVID-related delays.

Recommendation

It is recommended that the Board authorize the County Mayor or County Mayor's Designee to extend the Ash Reuse Pilot Study Project and continue the Agreement between DSWM and Covanta to process ash from the RRF to be reused for beneficial purposes as a material substitute in the production of cement and extend the Pilot Study by another 12 months due to COVID-related delays (see Attachment 2). The process materials include metals, magnetic solids, and processed ash that will be transported offsite to be reused for beneficial purposes.

Delegated Authority

The Board authorizes the County Mayor or County Mayor's Designee to: (i) extend the Ash Reuse Pilot Study Project; and (ii) execute a 12-month extension agreement with Covanta, to further a Pilot Study to process ash from the County's RRF. The processed ash will be transported offsite to be reused as a substitute for coal ash in the production of cement.

Scope
The impact of this item is countywide in nature. The County's RRF located in the City of Doral, Florida serves the municipal solid waste disposal needs of the residents of Miami-Dade County and is the cornerstone of the County's integrated solid waste management system.

Fiscal Impact/Funding Source
The total ash processed shall not exceed 75,000 tons, unless mutually agreed to by both parties.
In recognition that the processing of ash and reuse of the materials from processed ash is environmentally sound and will extend the life of the Ash Landfill, the County will pay Covanta $2.00 for each ton of ash processed.

The County will reimburse Covanta for the reasonable cost of transportation of only the processed ash to be reused as a substitute for coal ash by Titan, up to $6.00/ton.

The funding source for this project is DSWM proprietary funds.

DSWM should potentially have a reoccurring savings from not having to landfill ash at the RRF. DSWM shall determine the long-term viability of this project and report back to the Board.

Background
DSWM partnered with UF, in cooperation with Titan and Covanta Energy to explore the use of Waste-to-Energy ("WTE") bottom ash as a kiln feed ingredient for cement production. Cement production facilities commonly utilize waste materials (e.g., coal ash, steel slag) as kiln feed ingredients, and given the proximity of the Titan facility to the RRF, use of WTE bottom ash in a similar manner appears as a potential avenue for enhancing the County's recycling efforts.

In summary, the research focused on cement and cement products produced using RRF bottom ash and compared them to similar cement products made with no bottom ash. Through a series of environmental tests, the research team reported no increased direct exposure or leaching risk when WTE bottom ash was incorporated into cement production at replacement percentages of 3% of raw material. Characteristics such as mineralogical composition, heat of hydration, and compressive strength were found similar between WTE bottom ash amended cement and control cement.

On April 24, 2020, DSWM, Covanta, and Titan Florida LLC ("Titan") Pennsuco Cement Plant, located at 11000 NW 121st Way in Medley, presented a plan for processing and hauling ash from the RRF to Titan to reuse in cement production. Under this plan, Covanta would need to remove additional metals from the ash and DSWM would compensate Covanta for processing up to 75,000 tons of ash.

On July 15, 2020, FDEP approved DSWM's request for a 12-month pilot study (the "Pilot Study") (see Attachment 3).

On January 2021, the County agreed to make a portion of the ash landfill, at the RRF available to Covanta for operation of a mobile metals processing unit (the "Unit"), by Covanta or its affiliate, Covanta Metals Marketing, LLC for 12 months so that a cleaner product could be tested by Titan (see Attachment 4). However, due to delays caused by the Coronavirus pandemic and plant outages at Titan, the Pilot Study did not commence until February 2021. DSWM requested an extension on the Pilot Study from FDEP to better evaluate the feasibility of incorporating the County's bottom ash in the production of cement by Titan.

On December 21, 2021, FDEP advised that it had no objections to an additional 12-month project extension through February 2023 (see Attachment 5).

There are a number of potential direct and indirect financial and environmental benefits that will accrue to the County, should the RRF ash be utilized as a suitable coal ash substitute including:

- Reducing the amount of ash that will have to be landfilled.
- Extending the life of the existing Ash Landfill.
- Allowing for more capacity, thereby postponing the need for a new ash landfill.
- Increasing recycling rates in order to help reach the Florida adopted 75% recycling goal.
- Enhancing the protection of the environment since WTE ash has fewer contaminants than coal ash.
- Reducing the cost of building materials by avoiding importation of raw materials from other sources.
- Achieving sustainability with a true closed loop system of reusable ash.
- Receiving credit towards Florida's recycling goal.

Jimmy Morales
Chief Operations Officer

Use of Waste-to-Energy Bottom Ash from the Miami-Dade Renewable Energy Facility as a Kiln Feed Component in the Manufacture of Portland Cement

Draft Final Report

August, 2018

Prepared for:

Miami-Dade County Department of Solid Waste Management

Prepared by:

Department of Environmental Engineering Sciences

Engineering School of Sustainable Infrastructure and Environment (ESSIE)

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and

The Hinkley Center for Solid and Hazardous Waste Management

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Executive Summary

The University of Florida assisted Miami-Dade County in assessing the feasibility of incorporating waste-to-energy (WTE) bottom ash in cement production. In partnership with Covanta Energy, Titan Pennsuco cement, and The Hinkley Center for Solid and Hazardous Waste at the University of Florida, a full-scale pilot test was performed in which approximately 1,000 tons of bottom ash-amended clinker was produced. Environmental and physical testing were performed on bottom ash-amended cement and control cement products to assess any differences between the two cements. An extensive suite of leaching tests was performed, including several batch leaching tests and a monolithic leaching test. Results of these tests indicate that there is no excess leaching risk associated with incorporating approximately 3% of WTE bottom ash in cement production; there were no significant differences in the leaching characteristics of the WTE bottom ash amended cement compared to control cement. Additionally, physical testing performed for mortar properties indicates that WTE bottom ash-amended cement manifests no significant performance loss in comparison to control cements. A commentary on the risks associated with the tested materials is provided, as well as an analysis of the South Florida WTE and cement markets to provide insights into the feasibility of using WTE bottom ash in cement kiln feed.

1.0 Overview

1.1 Project Overview

The Miami-Dade County Department of Solid Waste Management sought to evaluate whether waste-to-energy bottom ash (WTE BA) from the Miami-Dade Resource Recovery Facility (RRF) in Doral, Florida, could be used beneficially as a kiln feed component in the manufacture of Portland cement. To test the suitability of WTE BA for this use, a 3-hour pilot test was performed at the Titan Pennsuco cement kiln located in Medley, Florida, around five miles north of the RRF (see figure 1.1). The RRF produces approximately 142,000 tons of ash per year, all of which is currently managed through monofill disposal. The mineral composition of the ash, in particular, the presence of iron, aluminum, and silicon oxides, makes it suitable for recycling as cement kiln feed. This research is relevant because cement manufacturers are experiencing cost increases as a result of their use of coal fly ash as a kiln feed component. This is because electricity producers, for a variety of reasons, have been transitioning from coal to natural gas, and this has led to a decrease in the supply of coal fly ash.

For the one-day test, Covanta and Miami-Dade County provided approximately 400 tons of WTE BA, which generated about 1,000 tons of clinker. The University of Florida research team performed a series of tests on the WTE BA-amended cement and cement products (concrete and mortars) to access their physical properties and the environmental implications of any mobility of the trace elements contained within them. The results of these leaching and physical tests were then compared to a control sample representing a composite of the cements produced in different kilns around Florida (without WTE BA).

This project points to two benefits resulting from the use of WTE BA in Portland cement production. First, using WTE BA in cement production can decrease the amount of the material that needs to be landfilled, increasing the lifespan of the landfill. Second, cement manufacturers can replace a portion of the coal fly ash they use in kiln feed with cheaper WTE BA, reducing their costs.

1.2 Key Parties and Responsibilities

Four entities contributed to this project: the Miami-Dade County Department of Solid Waste Management , Covanta Energy, Titan Florida, and the University of Florida through the Hinkley Center for Solid and Hazardous Waste Management. A brief description of their roles and responsibilities is presented below.

- **Miami-Dade County Department of Solid Waste Management .** Owner of the Miami-Dade Resource Recovery Facility (RRF). For this project, Miami-Dade County requested the research services of the University of Florida to determine whether the WTE BA produced at the RRF would be suitable as a replacement for other raw materials in cement manufacture.
- **Covanta Energy.** Operator of the Miami-Dade RRF. Covanta processes around 1.3 million tons of municipal solid waste (MSW) per year, which results in the production of approximately 142,000 tons of WTE BA, which is currently discarded in a monofill (a landfill dedicated solely to the disposal of a single waste material). Covanta was responsible for supplying the WTE BA needed for the pilot test and for authorizing University of Florida researchers to collect samples of it.
- **Titan Florida, LLC.** Titan operates the Pennsuco Cement facility in Medley, Florida. The facility includes a Portland cement plant (which uses a dry process), an aggregate plant, two concrete plants, and a cement block plant. The Portland cement plant produces approximately 2.2 million tons of clinker and 2.4 million tons of cement annually. The facility also has a raw materials storage building, clinker and cement handling and storage systems, and product packaging and transport facilities. For this project, Titan was responsible for the operation of the plant during the pilot test and for authorizing University of Florida researchers to collect samples of control clinker, WTE BA-amended clinker, and WTE BA-amended cement.
- **The University of Florida.** Through the Hinkley Center for Solid and Hazardous Waste Management, UF researchers were responsible for testing, analyzing, and evaluating the WTE BA, clinker, and cement produced during the pilot test and for comparing those products to selected control samples.

1.3 Project Objectives

This research sought to evaluate the feasibility of using WTE BA from the Miami-Dade Resource Recovery Facility as kiln feed replacement in cement manufacture and determine whether WTE BA-amended cement is of similar quality to ordinary Portland cement. The research also sought to assess the distinct physical characteristics of WTE BA-amended mortar and the potential environmental risks posed by the leaching of trace elements from cement products made with WTE BA-amended cement.

2.0 Literature Review

Portland cement is obtained from the pulverization of Portland cement clinker, which is obtained from the reaction of calcium silicates, aluminum oxides, iron oxides, and other oxides. The major composition of clinker is approximately 63-67% CaO, 19-23% SiO_2, 3-7% Al_2O_3, and 1.5-4.5% Fe_2O_3 (Bye, G.C., 1999). The four main mineral phases observed are: alite (tricalcium silicate, commonly expressed in cement chemistry as C_3S), belite (dicalcium silite or C_2S), aluminate (tricalcium aluminate or C_3A), and ferrite (tetracalcium alumino ferrite or C_4AF) (Bye, G.C., 1999). Bogue's equations, presented below, are commonly used to calculate these phases in the clinker.

$$C_4AF = 3.04Fe_2O_3$$
$$C_3A = 2.65Al_2O_3 - 1.69Fe_2O_3$$
$$C_2S = 8.60SiO_2 + 1.08Fe_2O_3 + 5.07Al_2O_3 - 3.07CaO$$
$$C_3S = 4.07CaO - 7.60SiO_2 - 1.43Fe_2O_3 - 6.72Al_2O_3$$

Given the presence of these compounds in waste-to-energy bottom ash, several researchers have studied the possibility of using it in the manufacture of cement. Apart from assessing the effect of the ash on the quality of the cement produced (by assessing parameters such as compressive strength and setting times), researchers have also focused on the environmental implications of this process modification. This section will describe the results obtained by different researchers, including the physical characteristics of the cements produced and the leaching behavior of trace elements in these cements.

2.1 Composition of Ash-Amended Cement

Krammart and Tangtermsirikul (2004) used BA from an incinerator in Thailand to create clinker in the laboratory at raw material replacements of 5% and 10%. The chemical composition of the ash-amended clinker was similar to that of ordinary Portland cement (OPC) clinker. However, when the researchers calculated the mineral phases in the clinker, the ash-amended clinker had a lower content of C_3S and a higher content of C_2S when compared to OPC clinker. This is explained by the stronger presence of SiO_2 in ash-amended clinkers (Krammart, P., & Tangtermsirikul, S., 2004).

The use of waste-to-energy fly ash (WTE FA) in cement kilns has also been the object of study by several researchers. Saikia et al. (2007) collected samples from two facilities and created cement clinker at a laboratory scale; unlike other studies, these researchers used high percentages of ash replacement in the raw mix, varying from 44-50%. X-ray diffraction (XRD) was used to determine the phase composition of the clinkers. The results of this study show the possibility of creating an ash-amended clinker with all mineral phases characteristic of OPC clinker. The presence of chlorides in the ash was observed to generate problems during the process; however, a simple pre-treatment of the ash, such as washing, was observed to positively affect the formation of clinkers (Saikia et al., 2007).

Pre-treatment of the ash to reduce chloride content in WTE BA and WTE FA was also studied by Pan et al. (2008). A treatment of water washing followed by an acid wash with an acetic acid solution was found to reduce chloride content in the ashes by more than 90%. The washed ashes were used to create clinker at small raw material replacement percentages. The chemical composition of the ash-amended clinkers, obtained by means of XRD, were similar to OPC clinker; mineral phases calculated using Bogue's equations were also comparable to those in the control (Pan et al., 2008).

Lam et al. (2010) studied the effects of WTE BA and WTE FA on the properties of clinker produced with ash replacements ranging from 2-8%. By means of XRD and X-ray fluorescence techniques, the authors analyzed the phase chemistry and chemical composition of the clinkers and compared them to OPC clinker. They found that WTE BA additions of 2-6% resulted in a clinker with a C_3S content ranging from 37-47 wt%, a figure comparable to OPC clinker. This number was reduced when the ash addition was increased to 8%, which could be explained by a higher free-lime content, which results in the decomposition of C_3S to C_2S. Clinkers produced with WTE FA did not show a good correlation with OPC clinker, especially the low presence of the C_3S phase, which could be caused by insufficient lime for the reaction or a high concentrations of chlorides inhibiting the formation of this phase (Lam et al., 2010).

2.2 Compressive Strength, Consistency, and Setting Times

Kikuchi (2001) compared the compressive strength of ash-amended cement mortar against OPC mortar in order to assess whether an ash-amended product of acceptable quality could be produced. Two blends were analyzed, blend one contained approximately 30% of MSWI ash and blend two contained approximately 28% of MSWI ash and 10% sewage sludge ash. Results showed that both blends had lower compression strength due to a lack of alite formation but were considered sufficient for practical use. Krammart and Tangtermsirikul (2004) performed similar tests and observed that the strength of the ash-amended mortar was lower than that of control mortar created with OPC. The difference was more noticeable when the percentage of WTE ash in the raw meal was increased. This lower compressive strength is explained by the lower content of C_3S in the ash-amended cement. Pan et al. (2008) analyzed clinker samples, one with 1.75% FA and another with 3.5% BA. Positive results were obtained when the compressive strength of the ash-amended cements were compared against Type II Portland cement (Pan et al., 2008). Ghouleh and Shao (2018) analyzed a mixture of FA and waste-lime based on CO_2 reactivity, lowest clinkering temperature and the amount of virgin additives needed. Lime is typically used to neutralize the acidity of flue-gas and its waste product is disposed of by landfill. The mixture that was chosen consisted of 42.8% FA and 42.8% waste-lime and was found to have 6.7% CO_2 uptake, a clinkering temperature of 1000°C and only needed 14.4% of virgin additives. This blend was found to have 85% of the strength of OPC.

Increased setting times in ash-amended cements were observed by Krammart and Tangtermsirikul (2004). The reason for the increased setting time was attributed to the lower content of C_3S and higher content of C_2S in ash-amended clinkers. Additionally, the consistency of the ash-amended cement pastes created by Krammart and Tangtermsirikul (2004) was slightly higher than the control. In the study by Pan et al. (2008), high heavy metal concentrations, such as ZnO and PbO, resulted in increased setting times. These setting-time results were opposite to those obtained by Kikuchi (2001), where setting times from ash-amended cements were shorter than those from OPC.

2.3 Mobility of Trace Elements in Ash-Amended Cement

Kikuchi (2001) studied the mobility of trace elements in ash-amended cement by means of a batch leaching test. The test consisted of measurements taken on a mixture of pulverized ash-amended cement and water at a liquid-to-solid ratio of 10 and a pH of 5-7 extracted for a period of 6 hours. The results showed that concentrations of elements such as cadmium, lead, mercury, and copper were low and that the material therefore posed no environmental risk (Kikuchi., 2001).

Saikia et al. (2007) studied not only the leaching behavior of trace elements in ash-amended clinkers but also their volatilization. By means of a simple mass balance, the researchers used measurements of the total concentration of trace elements in raw mix and produced clinker to calculate the amounts of elements liberated. Additionally, US EPA Method 1312, *Synthetic Precipitation Leaching Procedure* (SPLP), was performed to determine the leachability of elements in ash-amended clinker. It was observed that elements of concern such as lead and cadmium were mostly volatilized (up to 97% volatilization); this could be explained by the presence of those elements as chloride compounds with boiling points lower than the temperatures observed in the kiln (Saikia et al., 2007). Other elements, such as tin, molybdenum, chromium, arsenic, and selenium, were observed to remain stable in the clinker matrix (low mobilization during SPLP), possibly due to the formation of stable compounds with the lime, alumina, and silica present in the raw mix. Also, part of the study performed by Lam et al. (2010) included performing US EPA Method 1311, *Toxicity Characteristic Leaching Procedure* (TCLP), on ash-amended clinker. Their results indicated that mobility of trace elements from ash-amended clinkers is below applicable TCLP limits (and below US toxicity characteristic (TC) limits) regardless of the type of ash used. The leaching performance of the FA and waste-lime mixture by Ghouleh and Shao (2018) also provided positive results. This study also used TCLP and SPLP test methods and found that heavy metals in all of the solutions were below regulatory limits. It was noted by the authors that while the clinker product was within regulation more thorough and targeted evaluations regarding dioxins, furans, PAHs, VOCs and chlorine are needed.

2.4 International WTE Ash Use in Cement Kilns

Cement is an essential material in infrastructure and transportation construction all over the world. Economic and population growth have increased the global demand for cement, and many cement plants now face competitive challenges. Cement production requires extensive material and energy resources; therefore, cement producers continually strive to develop alternatives in order to conserve resources. Furthermore, limitations set on landfilling due to diminished land resources have compelled municipalities to increase landfill-use fees to encourage alternatives to landfills (Theulenm, 2015).

Outside the US, use of WTE ash in cement kilns to promote energy and material conservation as well as to reduce the demand on landfills has begun to become more common. For example, because strict regulations on waste management have been enacted in the EU, a major push is occurring there toward achieving what is known as a circular economy, which seeks to close the material-use loop by reusing all generated waste. This has led to greater interest in constructing co-processing plants that generate energy through waste incineration and use the resulting ash in cement production.

In the Netherlands, for example, incineration is used extensively as a waste management method; that nation has also been at the forefront in using refuse-derived fuels in cement kilns (Chatziaras et al., 2016). Under the so-called Green Deal, the Netherlands has set a goal of increasing recycling by 100 %wt of WTE ash in order to limit the number of new landfills required (Caprai et al., 2018). Wiles (1995) notes that approximately 60% of the Netherland's BA production is being utilized as embankments, road base and aggregate in concrete and asphaltic concrete.

Some research aimed at increasing the usefulness of WTE ash looks at treatment methods including hydrothermal treatment and washing and sieving (Caprai et al., 2018)(Alam et al., 2017). As of 2015, Belgium, a leader alongside the Netherlands in promoting sustainability in waste management, generated MSW at an annual per capita rate of 4.7 Mt; 35% of that was incinerated, 401 kt of bottom ash was produced, and 174 kt was processed for use as a replacement in kiln feed. The WTE ash generated in the Belgian co-processing plants is treated to promote safe recycling practices. The treatment process places limits on the leaching of organic contaminants as well as on chlorine and fluorine. (Minane et al., 2017) (Joseph et al., 2017). Similarly, since 1974, Denmark's WTE BA has been utilized as a subgrade material in infrastructure and road construction projects. Bottom ash is also being used as a kiln feed replacement on a limited trial basis. (Ornebjerg, 2006).

Similar progress is occurring in Asia. In Japan, for example, a company called Eco-cement produces large quantities of ash-amended clinker in co-processing plants, with the resulting WTE BA and WTE FA being used in kilns; the process uses a treatment method known as solidification/stabilization, which aims to immobilize hazardous contaminants. Using this method, pretreated WTE FA and WTE BA can replace about 50% of the aggregate in cement product without affecting the durability of the final product. As a whole Japan recycles more than 44% of the mixed WTE ash it generates in production cement clinker (Lam and Alvin., 2010).

Table 2.1 provides current research that seeks to progress the utilization of WTE ash in cement production by broadening the knowledge related to the composition, physical characteristics and the leachability of ash-amended cement. Although many nations have begun to use co-processing plants to conserve resources and have integrated WTE ash in construction, much more work needs to be done globally, including in the US, to establish the rigorous source segregation, incineration, and treatment processes necessary to widely utilize WTE ash as a replacement kiln feed in cement production.

Table 2.1. A chronological list of some research on information regarding the incorporation of WTE FA and BA in the manufacture of cement.

Authors - Country	*Objective and Type of MSWI Ash Evaluated*	*Experimental Methodology*	*Observations*
(Shih et al., 2003) - Taiwan	· MSWI ash utilization as a replacement of raw mix in the production of cement · BA and Magnet-Repelled (MR) BA	· Dried before experimental tests · Chloride and sulfate concentrations in ashes · Materials were digested and underwent inductively plasma spectrometry (ICP) and XRD was performed to identify crystalline phases · Unconfined compressive strength (UCS) testing on clinker · HM and LSF calculated on clinkers	· Sieving, self-grinding and magnet separation processes are necessary for removing debris, salt and metallic content · Pre-treated BA and MR BA are in compliance at percentages <5% · Large percentages (10% or more) strength is hindered due to deficient formation of calcium silicate · At 15% as replacement compliance can be met by adjusting the chemical composition by adding calcium oxide · HM decreases with the increase of ash replacement resulting in a poor strength development · At higher percentage replacements, the addition of CAO to the mix resulted in an improvement of HM and LSF
(Aubert et al., 2003) - France	· Investigating the effects of a new physiochemical treatment process (Revasol Process) on FA for the utilization in concrete. · Treated FA (TFA)	· Revasol Process involves reducing the soluble fraction, fixing heavy metals and eliminating dioxins · TFA replacement values of 12.5% and 50% for ash-amended concrete · Analysis of compressive strength, setting times and leaching	· Physical properties such as gas permeability, porosity accessible to water and total porosity are not significantly modified by TFA · No significant loss of mechanical strength with the substitution of TFA in place of cement for concrete · Crushed concrete leaching – for all mixtures leached element concentration remained constant; except for chromium and sulfates · Monolithic concrete leaching - all concentrations were within regulation · For both leaching tests the higher the substitution the higher the Cr, As and sulfates leached concentrations
(Krammart and Tangtermsirikul., 2004) - Thailand	· Investigated using MSWI BA as a part of the cement raw materials · BA	· Replacement in kiln feed of 5 and 10% weight · Analysis for setting time, compressive strength, and expansion in sulfate solution	· Decreased compressive strength from ash – amended cement when compared to a control cement, and it was a function of the % replacement · Decreased sulfate expansion when compared to control cement (higher resistance to sulfate attacks which result in cracks or loss of bond between cement and aggregates in concrete) · Longer setting time than control cement due to lower content of lower C_3S and higher C_2S than the control
(Aubert et al., 2005) - France	· Investigates two stabilization process for the incorporation of FA in mortars	· Ash from French incinerator due to it being rich in sulfates and heavy metals	· Washing in both processes dissolved chlorides in ash

	· FA	· Two stabilization processes used - Stabilization process "A" based on washing, phosphation and calcination and stabilization modified process "B" is to eliminate metallic aluminum and sulfate · ICP, water content and loss of ignition were analyzed · XRD and leaching behavior analyzed on products · Reactivity in presence of calcium hydroxide analyzed by studying two pastes made of 75% TFA and 25% calcium hydroxide	· Modifications in stabilization increased the surface area of the TFA and reduction in the stabilization of chromium, selenium and antimony · TFA-B was free of metallic aluminum and sulfate · TFA-B is more porous than TFA-A and contained particles of neo-formed calcite · Leaching tests on TFA-A process showed lack of chromium stabilization and poor efficiency for antimony and cadmium · Reactivity results suggests TFA can be considered as pozzolanic addition
(Wey et al., 2006) - Taiwan	· Studies continuous sintering effects of FA with a rotary kiln to observe a reduction in heavy metal concentrations · FA	· Major factors, retention time and temperature, were analyzed due to their effect of the harmful products of sintering FA · Analysis of water-extraction process to evaluate possibilities of lowering TCLP concentrations	· Sintering under 900°C declined concentration of Pb · Water-washing treatment decreased the sintering temperature and time, as well as reduced chloride concentrations from 17.7% to 9.4% · Water-washing decreased TCLP concentrations but Pb still exceeded regulation
(Pan., et al 2007) - Taiwan	· Investigates the possibility of incorporating MSWI ash as a raw material in cement production · FA and BA	· First material was dried, ground and sieved then different washing techniques were utilized for the removal of chloride. · FA replacement percentage of 1.75% and Ba replacement percentage of 3.5% · · XRF determined chemical composition · Maximum concentration determined by chloride concentration · Compressive strength was tested on clinker	· Addition of FA and BA increased P_2O_5 production; when P_2O_5 exceeds 0.5% the production of C_3A will be reduced which reduces the strength · Setting times were increased by approximately 15%; this is explained by the heavy metal content · Compressive strength was not altered by the addition of FA and BA.
(Saikia et al., 2007) - Japan	· Incorporation of MSWI FA in cement clinkers · FA and washed FA	· High percentage replacement of ash in clinker, 44 – 50% weight · XRD on ashes, mix, and clinker · SPLP and hydration behavior on clinkers	· MSW ash shows to be suitable as a high percentage kiln feed along with $CaCO_3$, SiO_2, and Fe_2O_3 · Washing of the ash reduced Cl- content therefore reducing chloride related problems during the clinkerization such as increased free CaO content · Although total concentration of some metals is high, SPLP results indicate decreased leaching
(Lam et al., 2010a) - China	· Investigates the incorporation of MSWI ash in cement clinkerization	· Replacement in kiln feed of 2-8% weight · XRD and TCLP on clinkers	· Addition of up to 6% of BA results in phase composition comparable with OPC clinker

	· BA and FA		· Insufficient CaO for alite formation in FA amended clinkers · Low leachability of heavy metals in all ash amended clinkers
(Siddique, 2010) - India	· Literature review of the characteristics of MSW ash and the effects on cement and mortar when MSW ash is incorporated in concrete · FA and BA	· Literature analysis of physical, chemical and mineralogical composition of MSW FA · Literature analysis of hydration characteristics, settings times, compressive strength, sulfate resistance and mass loss of cement and mortar	· Literature analysis concludes use of MSW FA at replacement values up to 10% does not significantly affect compressive strength. · Clinkers can be made with 44% or more of FA with the incorporation of $CaCO_3$ and small amounts of SiO_2 and Fe_2O_3 · FA increases flow and initial and final settings times. Dramatic increase in setting times when (10%-15%) of FA was used · FA does not affect shrinkage and mass loss of cement and mortar.
(Wang et al., 2010) - China	· Studies the incorporation of water-washed MSWI FA into clinker production · FA	· Characterization of clinker with XRF, ISP and XRD for phase formation. · Analysis of the effects of water-washing on clinkers was studied using Solid-Waste Procedure for Leaching Toxicity · Analysis of compressive strength, setting times and leaching concentrations of clinker	· Zn, Cu and Pb are most concentrated heavy metals found along with high Ca content · Water-washing reduced chloride content to 0.06%. Typical concentrations chloride in WTE FA in China is 10-20%. · Leachate concentrations are low except for Zn. · Settings times were shorter when compared to clinker without FA. Negligible effects of compressive strength.
(Lam et al., 2011) - China	· Investigates the incorporation of MSWI ash in cement clinkerization · BA, FA and Water-treated FA (FAW)	· Replacement in kiln feed of 2-8% weight · XRD and TCLP on clinkers	· Replacements up to 6% result in clinkers with phase composition comparable to (OPC) · 8% replacement results in an increase of free lime content, decreasing C_3S content · Use of FA results in insufficient CaO for alite formation · Low leachability of heavy metals in all ash amended clinkers
(Quina et al., 2013) - Portugal	· Studies stabilization/solidification treatment on MSWI ash. · FA	· Analysis of initial and final setting times, mechanical strength, total availability and leaching from products · Monolithic leaching tests to estimate emissions of pollutants over 48 hours and 64 days	· Setting times were reduced when soluble phosphates were used · UCS was reduced due to matrix dissolution during immersion, but all treatments met requirements · Leaching tests for both unmolded and molded materials were exceeded due to chloride concentrations · Adding chemical additives such as soluble silicates and soluble phosphates produce positive effects for most paraments except for soluble salts

(Garcia-Lodeiro et al., 2015) - Spain	· Investigates the incorporation of MSWI ash in Alkali-activated hybrid Cements · FA and BA	· Incineration ash replacement percentage of 40% (17% FA and 83% BA · Analysis of compressive strength · XRF for elemental determination · TCLP and ANSI/ANS for determination for leaching of heavy metals	· The compressive strength was determined to be 33MPa; surpassing regulations · Alkaline activation lowered the number of metal species that could possibly leach. Resulting matrices had solidified and stabilized · Concentration of chloride ions exceeded regulation
(Li, Y. et al., 2016) - China	· Analysis of MSWI BA reuse in cement production · BA	· BA replacement percentage of 9% · XRF for determination of chemical composition at different particle sizes	· CaO and chloride concentrations decreased as the particle size increased · Al_2O_3 and Fe_2O_3 was stable with varying particle size · Chloride in sieved 8 portion exceeded the allowable limit for clinker production · Heavy metal concentrations were high but met requirements
(Li, J. et al., 2017) - Singapore	· Investigates the potential of utilizing MSWI FA as a cement supplement in strain hardening cementitious composites (SHCC) · FA	· FA replacement percentages of 20%, 30% and 40% were tested · Scanning electron microscope on FA and SHCC · Energy-dispersive X-Ray Spectroscopy and XRD on SHCC · Compression and Leaching Tests on monolithic and granular SHCC	· FA disqualified as a conventional pozzolan due to chemical composition · Replacements of up to 20% maintains compressive and tensile strength of SHCC · Both monolithic and granular leaching of heavy metals complied with regulations. Suggesting SHCC binder is effective in immobilizing contaminants
(Yang et al., 2017) - China	· Investigates the feasibility of using washed MSWI FA and BA as a supplementary material in the production of blended cement · TFA and TBA	· Cement composites with 10-50 %wt for the analysis of setting times, compressive strength, and leaching of heavy metals · Hydration characteristics were analyzed using XRD and SEM	· The use of FA and BA reduced the strength of the composites and increased setting times. · Maximum replacement range of waste FA and BA are 40% and 20%, respectively · TCLP results indicate that heavy metal leaching is within regulation
(Ghouleh, Z. and Shao, Y., 2018) - Canada	· Evaluates the feasibility of utilizing outputs of energy, ash and CO_2 in the manufacture of cement · FA	· 85%wt MSW Residues (42.8% FA and 42.8% Waste-Lime) · Thermal analysis for clinkering regimen · Carbonation, hydration and compressive performances tests · XRD, SEM, TCLP and SPLP on clinkers	· All determined temperatures were below conventional cement clinkering (no additional energy) · Highest binding strength was found by clinkering at 1000ºC which was at 85% of OPC · Leaching criteria passed for both normal and specialized landfill disposal characterizations

3.0 Experimental Methodology

3.1 General Experimental Approach

Covanta and Miami-Dade County provided approximately 400 tons of WTE BA produced at the RRF to the Titan Pennsuco facility for the pilot cement production test. The BA was transported to the Pennsuco facility's covered storage area over a 5-day period. Approximately 1,000 tons of clinker were produced during a three-hour pilot test conducted on February 2, 2018. In order to assess the performance and environmental impact of WTE BA-amended cement, the UF research team performed a series of tests to determine the mobility of trace elements in the cement and the strength of the cement and cement products (concrete and mortar), comparing those results to a control sample. The control cement was a composite of cements (without WTE BA) produced at different kilns around Florida.

3.2 Sample Collection

The bottom ash was shipped from the RRF to the Pennsuco facility in 8- hour-per-day shifts. Eight grab samples were taken every hour and eventually transferred to a 5-gallon HDPE bucket to represent a daily composite sample. The resulting five 5-gallon HDPE buckets, each representing a daily sample, were then transported to UF and homogenized to produce a composite sample representing the ash produced at the RRF. The buckets were placed on a clean plastic tarp and mixed using a clean shovel. The resulting mixed sample was returned to the 5-gallon buckets and referred to as the BA composite sample.

Samples of a control clinker and an ash-amended clinker were also collected. The control clinker sample was collected in the weeks prior to the pilot test. Both the control and ash-amended samples were collected only after the production process was stable. The samples were placed in two 5-gallon HDPE buckets each (two for control clinker and two for WTE BA-amended clinker). To avoid contamination of the ash-amended sample with any ordinary clinker present in the silos, both clinker samples were collected at a point in the clinker handling system before the storage silos. Prior to analysis, each two-bucket sample was mixed to generate homogeneous control clinker and WTE BA-amended clinker samples. The two buckets for each sample were placed on a clean plastic tarp and mixed using a clean shovel. The mixed samples were returned to the 5-gallon buckets and remained sealed until analysis.

The WTE BA-amended clinker was stored in a silo at the Pennsuco facility until it was used to manufacture cement. After the cement was produced, samples of BA-amended cement were collected by Pennsuco facility operators and given to the UF research team. The control cement was a composite of three cements purchased at a materials supply store that had been manufactured at three different cement kilns in Florida. The three cement specimens were mixed in equal proportions by weight to create the control cement used in the analysis.

3.3 Environmental Testing

A variety of environmental tests were performed on the BA, the clinker, the cement, and the two cement products (mortar and concrete) created using the control and ash-amended cements. Hazardous waste testing was conducted only on the WTE BA. Total concentration and X-ray diffraction tests were performed on the ash, the clinker and the ash-amended and control cements. Leaching tests were performed on the mortar and concrete specimens. Table 3.1 presents a list of all the environmental testing procedures performed on the samples. Table 3.2 provides a description of the leaching tests that were conducted. Concrete and mortar specimens were created from the control cement and the Miami-Dade RRF BA-amended cement using identical mix designs for both concrete specimens and identical mix designs for both mortar specimens; that is, the only variable altered in the concrete and mortar mix designs was the cement used. The suite of leaching tests was extensive and meant to give a full picture of any potential leaching risk posed by amending cement with WTE BA from the Miami-Dade RRF.

3.4 Cement Product Sample Preparation

Concrete specimens made using control cement and ash-amended cement were both mixed and cast in 4-inch-diameter by 8-inch-tall cylindrical molds according to ASTM C192, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*. Concrete specimens were allowed to set for 24 hours in a room-temperature environment under ambient indoor humidity conditions, at which point they were demolded and placed in a moist curing room for a period of 1 week (7 days), in an area protected from dripping water to minimize leaching and generate a conservative estimate of element release. After this time had elapsed, the cylinders were removed from the moist curing room and crushed and size-reduced according to the size ranges required by the leach testing methodology. To minimize exposure to the environment, the crushed concrete samples were contained in sealed plastic containers when not in use. Cylinders destined for use with EPA Method 1315 (monolithic tank leaching) were not crushed; in order to satisfy the liquid-to-surface area requirements of EPA Method 1315 with reasonably sized sample containers, they were instead cut in half using a concrete saw to create the test specimens. Cylinders that were used for EPA Method 1315 were not exposed to the moist curing environment and were prepared for leach testing after the 24-hour ambient curing period.

Mortar specimens for control cement and Miami-Dade RRF BA-amended cement were mixed in accordance with ASTM C305, *Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency*. Like the concrete specimens, the mortar specimens were cast in 4-inch-diameter by 8-inch-tall cylindrical molds that were allowed to set in a room-temperature environment under ambient indoor humidity for 24 hours. The cylinders were then placed in a moist curing room for a period of 1 week (7 days), in an area protected from dripping water to minimize leaching and generate a conservative estimate of element release. After this time had elapsed, the cylinders were removed from the moist curing room and crushed and size-reduced according to the size ranges required by the leach testing methodology. To minimize exposure to the environment, the crushed mortar samples were contained in a sealed plastic container when not in use. Cylinders destined for use with EPA Method 1315 were not crushed; to satisfy the liquid-to-surface area requirements of EPA Method 1315 with reasonably sized sample containers, they were instead cut in half using a concrete saw to create the test specimens. Cylinders that were used for EPA Method 1315 were not exposed to the moist curing environment and were prepared for leach testing after the 24-hour ambient curing period.

Table 3.1. Environmental testing protocols performed on experimental samples

Test	*Sample*			
	WTE BA	**Clinker***	**Cement***	**Cement products***
Method 3050 B Total	X	X	X	X
X-ray diffraction	X		X	
Method 1311, TCLP	X			
Method 1312, SPLP				X
Method 1313, pH stat				X
Method 1315, Monolith				X
Method 1316, Batch LS				X

**Cement products include mortar and concrete specimens described above.*

Table 3.2. Description of leaching procedures performed on control and ash-amended cement products

Test	*Description*
Method 1311 Toxicity Characteristic Leaching Procedure (TCLP)	Used to determine the hazardous nature of a waste per Resource Conservation and Recovery Act (RCRA). Batch test at liquid/solid ratio (LS) of 20 using an acetic acid solution that simulates landfill leachate. Results are compared to TC limits.
Method 1312 Synthetic Precipitation Leaching Procedure (SPLP)	Evaluates the leaching behavior of trace constituents under simulated rainwater exposure (sulfuric acid/nitric acid/water solution)
Method 1313 Liquid-Solid Partitioning as a Function of Extract pH Using a Parallel Batch Extraction Procedure (pH Stat)	Nine different batch extractions performed at predetermined pH values to determine the influence of pH on the mobility of elements. Uses DI water as extraction solution with nitric acid or sodium hydroxide added to modify the pH, as necessary.
Method 1315 Mass Transfer Rates of Constituents in Monolithic or Compacted Granular Materials Using a Semi-Dynamic Tank Leaching Procedures (Monolith)	This test determines the mobility of elements from a material in a monolith or compacted form as a function of time. The monolith is submerged in DI water and sampling occurs at specific time periods. The water is renewed with new DI water after each sampling event.
Method 1316 Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio in Solid Materials Using a Parallel Batch Procedure (Batch LS)	Aims to determine the influence of LS by means of five different batch extractions at specific LS each. Uses DI water as extraction solution. Duration of the test is dependent on the particle size of the sample.

3.5 Performance Testing

The BA-amended and control cements were further compared with respect to their intended performance. Concrete and mortar samples (both ash-amended and control) were examined to determine their physical characteristics using a series of tests including heat of hydration, compressive strength, and plastic properties. The testing methods performed are presented in table 3.3. Isothermal calorimetry is a common cement testing protocol that measures the heat flow of a hydrated cement, where heat flux is converted into a continuously monitored voltage. This test gives an indication of cement reactivity. Time of setting measurements are meant to give an indication of the setting time of a mortar mixture; they are thus another indicator of cement reactivity. The test is performed by calculating the force required to push plungers of different diameters through a cube-shaped mortar specimen as it sets; this allows the operator to construct a curve of penetration resistance versus time since mixing. Measurements are taken until the specimen reaches final set (4,000 PSI penetration resistance).

Flow table measurements provide an indication of the workability of a mortar mixture; the value of the measurement lies in the performance of the test material in comparison to a control mixture. In ASTM C109, the compressive strength of mortar was measured by crushing fabricated mortar cubes made from control cement and Miami-Dade RRF BA-amended cement, with all other mixture ingredients held equal, at prescribed times of 1, 3, 7, and 28 days after mixing. This test gave a direct indication of the strength of the cements. No performance testing was performed on concrete, as the goal of the experiment was to test cement properties, not aggregate properties; mortar is the most effective material for gauging the performance properties of cement because it eliminates outside effects from coarse aggregate.

Table 3.3. Performance testing methods

Property	*Method number*
Heat of hydration – Isothermal calorimetry	ASTM C1702
Plastic properties – Flow table and time of setting	ASTM C1437, ASTM C403
Mortar compressive strength	ASTM C109

4.0 Results

4.1 Characterization of Ash, Clinker, and Cement

XRD results for the control and BA amended cements are shown in figure 4.1. The XRD results and major peaks were nearly identical and indicate a similar mineralogical structure. Percent compositions for each cement are provided in tables 4.1 and 4.2.

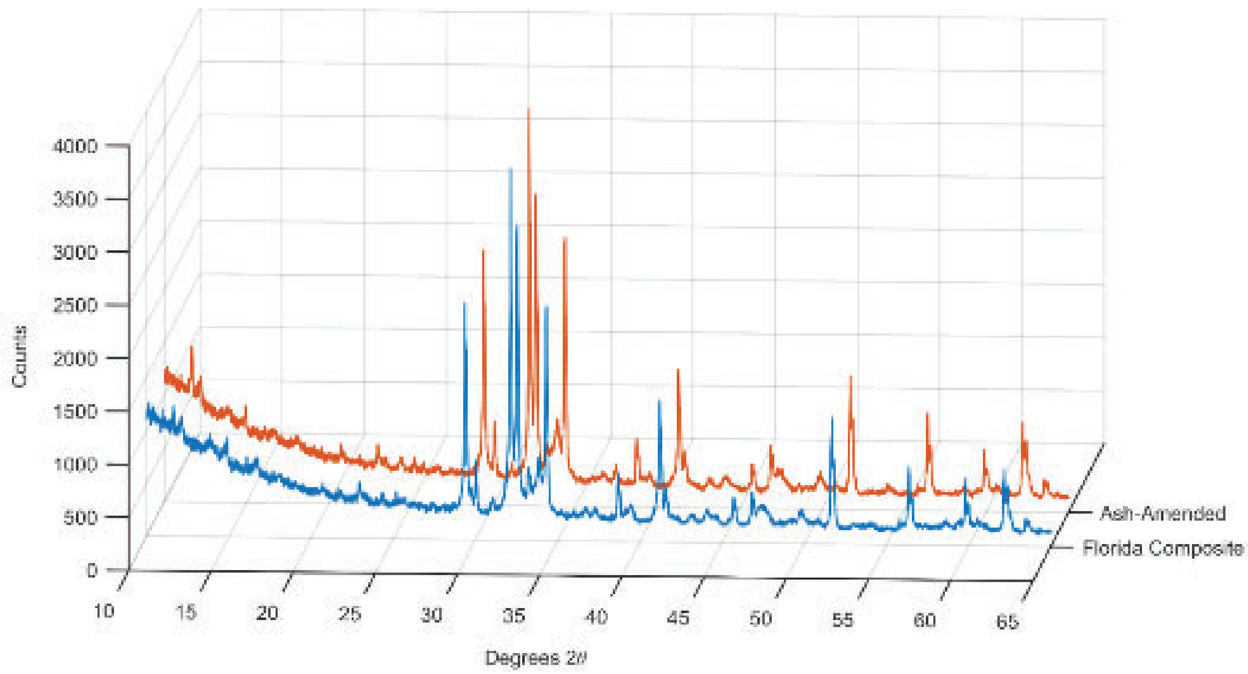

Figure 4.1. XRD signatures for control and BA amended cement samples

Tables 4.1 and 4.2. Cement composition results for control and BA-amended cement by XRD

Control cement			*BA-amended cement*		
Parameter, goal	**Value**	**ESD**	**Parameter, goal**	**Value**	**ESD**
$\frac{C_3AOrt}{sum}$	0.0293	0.0016	$\frac{C_3AOrt}{sum}$	0.0224	0.0028
$\frac{C_3ACub}{sum}$	0	0	$\frac{C_3ACub}{sum}$	0.018	0.0028
$\frac{Anhydrite}{sum}$	0.00045	0.00037	$\frac{Anhydrite}{sum}$	0.0103	0.001
$\frac{Bassanite}{sum}$	0.0124	0.0013	$\frac{Bassanite}{sum}$	0.0216	0.0011
$\frac{Belite}{sum}$	0.1577	0.0033	$\frac{Belite}{sum}$	0.2067	0.0025
$\frac{Calcite}{sum}$	0.0149	0.0013	$\frac{Calcite}{sum}$	0.0357	0.0016
$\frac{Ferrite}{sum}$	0.1404	0.0026	$\frac{Ferrite}{sum}$	0.1389	0.0015
$\frac{Gypsum}{sum}$	0.0222	0.0012	$\frac{Gypsum}{sum}$	0.0137	0.0011
$\frac{Syngenite}{sum}$	0.0169	0.0018	$\frac{Syngenite}{sum}$	0.00221	0.0024
$\frac{Thenardite}{sum}$	0.0204	0.0019	$\frac{Thenardite}{sum}$	0.0124	0.0012
$\frac{Alite}{sum}$	0.5853	0.0033	$\frac{Alite}{sum}$	0.4983	0.0025

4.2 Hazardous Waste Characterization

The composite bottom ash samples were tested using TCLP. Table 4.3 provides results for both TCLP extraction fluids; in all cases, the results came back non-hazardous as per RCRA toxicity characteristic (TC) limits. Fluid 2 is typically the more conservative fluid because it has higher TCLP leachate concentrations. Based on generator knowledge of WTE bottom ash, silver and mercury are not hazardous-waste concerns. As such, an analysis for mercury and silver was not included as part of this study.. The primary elements of concern in WTE hazardous-waste characterization are lead and cadmium, which, as shown in table 4.3, were below the TC limit. Values below the equipment detection limit are displayed with the convention, "< 'detection limit'".

Table 4.3. TCLP results on composite bottom-ash samples extracted with both TCLP fluids

	Sub-sample	*18-hour extract pH*	*Leached concentration (mg/L)*					
			As	**Ba**	**Ca**	**Cr**	**Pb**	**Se**
Fluid 1	1	11.73	< 0.004	2.96	< 0.001	0.0148	1.38	0.00860
	2	11.76	< 0.004	2.74	< 0.001	0.0216	0.845	0.00660
	3	11.67	< 0.004	3.01	< 0.001	0.0156	5.08	0.00800
	Avg	11.72	0.00400	2.90	0.00167	0.0173	2.43	0.00773
Fluid 2	1	8.43	0.0174	0.310	0.00730	0.0174	< 0.004	0.0121
	2	9.24	0.0178	0.400	0.00780	0.0140	0.0112	0.0100
	3	8.39	0.0242	0.290	0.00200	0.120	0.0086	0.00660
	Avg	8.69	0.0198	0.333	0.00570	0.0504	0.00793	0.0096

4.3 Total Concentration Characterization

All samples (clinker, cement, mortar, and concrete) were characterized as to their total environmentally available concentrations using a total solids digestion procedure (EPA Method 3050B). Total concentrations for select elements known to be constituents of potential concern for cement and cement-based products are displayed in tables 4.4 and 4.5 for control and BA-amended products. All samples were analyzed in triplicate. Florida Soil Cleanup Target Levels (SCTL) are displayed at the bottom of each table to benchmark the results. Comparing the cement, clinker, mortar, and concrete to a risk-based target level such as SCTL would not be appropriate unless the materials were somehow used in a manner similar to soil. However, they do provide a quick screening method for identifying which chemicals might trigger the most interest from a direct-exposure environmental perspective. Any elements not displayed are well below their respective SCTL benchmarks. Element concentrations found to be below detection limits are labeled "< 'detection limit'"

Table 4.4. Total concentrations for control clinker and cement products

	Sub-sample	*Total concentration (mg/kg)*									
		As	**Ba**	**Cd**	**Cr**	**Cu**	**Mo**	**Pb**	**Sb**	**Se**	**Zn**
Control clinker	1	3.55	190	1.60	183	170	4.00	1.30	3.85	2.50	386
	2	3.45	181	1.50	170	161	3.45	1.55	3.20	3.10	372
	3	3.15	182	1.60	193	165	3.50	2.35	5.25	2.75	389
	Avg	3.38	184	1.57	182	165	3.65	1.73	4.10	2.78	382
Control cement	1	12.6	281	2.35	98.2	151	28.8	31.1	3.05	2.30	332
	2	13.0	236	1.95	93.8	175	29.7	31.8	3.40	3.20	348
	3	15.4	311	2.85	118	184	34.7	36.8	2.40	3.00	396
	Avg	13.7	276	2.38	103	170	31.0	33.2	2.95	2.83	358
Control cement mortar	1	2.30	49.0	0.850	22.0	25.5	8.60	7.60	1.50	0.550	< 0.001
	2	4.25	62.4	1.20	29.4	39.3	10.8	9.70	0.750	1.20	< 0.001
	3	2.50	37.4	0.650	16.0	15.1	6.80	6.05	1.05	1.32	< 0.001
	Avg	3.02	49.6	0.900	22.4	26.6	8.72	7.78	1.10	1.02	0.500
Control cement concrete	1	5.90	76.6	1.00	31.0	54.0	11.3	11.4	2.80	1.25	105
	2	5.60	90.9	1.10	35.7	62.3	12.7	13.6	1.80	2.00	123
	3	5.45	74.1	0.80	31.3	62.2	11.2	12.8	2.70	1.00	116
	Avg	5.65	80.5	0.97	32.7	59.5	11.7	12.6	2.43	1.42	115
Residential soil cleanup target level		2.1	120	82	210	150	440	400	27	440	26,000
Commercial/ industrial soil cleanup target level		12	130,000	1700	470	89,000	11,000	1,400	370	11,000	630,000

Table 4.5. Total concentrations for Miami-Dade RRF bottom ash, bottom ash-amended clinker, and cement products

	Sub-sample	*Total concentration (mg/kg)*									
		As	**Ba**	**Cd**	**Cr**	**Cu**	**Mo**	**Pb**	**Sb**	**Se**	**Zn**
Miami-Dade bottom ash	1	26.7	459	10.2	98.3	4860	5.75	440	7.45	<0.002	2823
	2	33.5	356	9.85	91.5	1130	6.95	561	9.50	<0.002	1523
	3	22.4	385	7.85	77.9	33800	5.25	373	9.70	<0.002	1124
	Avg	27.5	400	9.30	89.2	13200	5.98	458	8.88	1.00	1823
Bottom ash-amended clinker	1	5.45	166	1.75	121	175	5.15	27.4	3.00	3.95	435
	2	5.70	146	1.75	138	188	5.60	21.9	4.40	1.00	443
	3	6.20	175	2.10	153	205	5.80	30.5	3.20	2.60	498
	Avg	5.78	162	1.87	137	189	5.52	26.6	3.53	2.52	459
Bottom ash-amended cement	1	5.30	175	2.25	150	208	6.00	45.6	3.10	2.90	503
	2	5.45	157	2.10	141	191	5.15	38.6	3.70	2.65	474
	3	5.50	167	2.35	150	206	5.65	45.5	3.10	2.70	496
	4	4.30	173	2.20	144	194	5.40	41.9	3.65	3.85	480
	5	5.60	183	2.35	150	206	5.90	46.4	3.35	2.70	498
	6	5.05	179	2.35	152	211	6.15	46.5	3.75	3.40	508
	Avg	5.20	172	2.27	148	203	5.71	44.0	3.44	3.03	493
Bottom ash-amended cement mortar	1	1.55	48.3	1.30	45.1	48.3	2.40	13.0	1.30	0.800	< 0.001
	2	2.05	65.9	1.80	66.8	73.6	3.00	17.5	1.10	1.25	< 0.001
	3	1.40	46.2	1.30	43.7	46.2	2.15	12.3	1.30	1.12	< 0.001
	Avg	1.67	53.5	1.47	51.9	56.0	2.52	14.2	1.23	1.06	0.500
Bottom ash-amended cement concrete	1	2.55	61.1	1.05	46.5	58.6	2.50	14.2	2.30	1.80	142
	2	2.20	47.4	1.05	46.1	59.1	2.30	13.9	3.25	1.25	139
	3	2.20	51.0	1.15	49.1	60.4	2.40	15.0	2.55	1.10	147
	Avg	2.32	53.2	1.08	47.2	59.3	2.40	14.4	2.70	1.38	143
Residential soil cleanup target level		2.1	120	82	210	150	440	400	27	440	26,000
Commercial/ industrial soil cleanup target level		12	130,000	1,700	470	89,000	11,000	1,400	370	11,000	630,000

Using the SCTL comparison as a screening tool to identify elements for further discussion from an environmental perspective, elements that emerged included arsenic, barium, copper, and lead. Although arsenic was present at elevated concentrations in the tested WTE bottom ash, the control cement sample actually had a greater concentration of arsenic than the ash-amended sample. The amount of ash added to the cement in the tests described here was simply not enough to make a difference; other materials in the control cement kiln feed contributed much more arsenic. Similar results were obtained for barium, copper, and lead. Although levels of these elements were somewhat elevated in the BA with respect to residential SCTL, concentrations were about the same as in the control cement. Concentrations of almost all elements in the ash-amended concrete were lower than the residential SCTL, with only antimony being slightly higher. But antimony levels were even higher in the control concrete specimens than they were in the BA-amended specimens.

4.4 SPLP Leaching Characterization

Table 4.6 presents SPLP leaching results for control and ash-amended crushed mortar samples. Florida's risk-based groundwater cleanup target level (GCTL) is used for comparison. This type of assessment might be used when determining whether crushed cement or mortar were to be land applied in some fashion, but even for the purpose of examining the differences between the two materials it provides a benchmark to identify which compounds might pose environmental risk. In the control mortar samples, molybdenum exceeded the GCTL (0.043 mg/L vs 0.035 mg/L); in the ash-amended samples, chromium was in excess of the GCTL (0.112 mg/L vs 0.1 mg/L). Aluminum was in excess in both mortar samples (1.01 mg/L and 0.766 mg/L); the GCTL aluminum limit of 0.2 mg/L, however, is not based on health risk (but rather a secondary standard) -- a typical health-based risk concentration is more on the order of 20 mg/L. Values below the detection limit of the equipment used for analysis are displayed with the convention, "< 'detection limit'".

Table 4.6. SPLP for crushed mortar samples

Element	*SPLP control mortar (mg/L)*	*SPLP ash-amended mortar (mg/L)*	*Florida groundwater cleanup target level (mg/L)*
Aluminum	1.02	0.766	0.200
Arsenic	< 0.004	< 0.004	0.01
Boron	0.0254	0.0216	1.40
Barium	0.413	0.301	2.00
Beryllium	< 0.001	< 0.001	0.004
Calcium	510	500	—
Cadmium	< 0.001	< 0.001	0.005
Cobalt	< 0.006	< 0.006	0.140
Chromium	0.0673	0.112	0.1
Copper	< 0.002	0.00300	1.0
Iron	< 0.002	0.0998	0.300
Potassium	12.7	15.5	—
Magnesium	0.0275	0.0540	—
Manganese	< 0.001	0.00360	0.0500
Molybdenum	0.0430	0.00700	0.035
Sodium	8.52	11.3	160
Nickel	0.002	< 0.001	0.100
Lead	< 0.004	<0.004	0.015
Antimony	< 0.003	< 0.003	0.006
Selenium	0.00460	0.00323	0.0500
Tin	< 0.002	< 0.002	42.0
Strontium	1.58	2.14	42.0
Titanium	0.00118	0.00260	—
Vanadium	< 0.001	< 0.001	0.0490
Zinc	0.0330	0.00700	5.0

Table 4.7 presents SPLP leaching results for control and ash-amended crushed concrete samples. The results were similar to the results obtained with the mortar samples: molybdenum exceeded the GCTL in the control samples (0.0403 mg/L vs 0.035 mg/L), chromium exceeded the GCTL in the ash-amended samples (0.109 mg/L vs 0.1 mg/L), and aluminum exceeded in both samples (1.02 mg/L and 0.841 mg/L).

Table 4.7. SPLP for crushed concrete samples

Element	*SPLP control concrete (mg/L)*	*SPLP ash-amended concrete (mg/L)*	*Florida groundwater cleanup target level (mg/L)*
Aluminum	1.02	0.841	0.200
Arsenic	< 0.004	< 0.004	0.01
Boron	0.0307	0.00523	1.40
Barium	0.304	0.190	2.00
Beryllium	< 0.001	< 0.001	0.004
Calcium	407	353	—
Cadmium	< 0.001	< 0.001	0.005
Cobalt	0.00137	0.00243	0.140
Chromium	0.0771	0.109	0.1
Copper	< 0.002	0.00363	1.0
Iron	0.0758	0.0437	0.300
Potassium	7.32	8.63	—
Magnesium	0.101	0.0770	—
Manganese	0.00180	0.00227	0.0500
Molybdenum	0.0403	0.00637	0.035
Sodium	7.07	4.87	160
Nickel	< 0.002	< 0.002	0.100
Lead	< 0.004	0.00523	0.015
Antimony	< 0.003	0.00360	0.006
Selenium	0.00237	0.00210	0.0500
Tin	< 0.002	< 0.002	4.2
Strontium	1.20	1.36	4.2
Titanium	0.00443	0.00167	—
Vanadium	< 0.001	0.00103	0.0490
Zinc	0.00867	0.0320	5.0

SPLP results for the mortar and concrete specimens support the contention that leaching (under conservative conditions created by the crushing of the material per required testing methodology) from the ash-amended cement produced in this study does not pose any added risk relative the control concrete. The leached concentrations were similar to those seen in other concrete leaching studies; the only time a risk-based threshold was exceeded in the ash-amended concrete was for chromium, and the degree of exceedance was minimal (0.11 mg/L in mortar and concrete versus the GCTL limit of 0.1 mg/L). Tests were performed on fresh and crushed concrete samples, and thus SPLP leaching can be considered conservative as the samples have not aged or been exposed to natural environmental conditions; the exposed surface area of crushed samples is also much higher than larger uncrushed samples (such as in-use concrete samples). Method 1315 results are displayed in the following section, whereby chromium leaching in ash-amended concrete specimens in a monolithic form is near or below the detection limits of the equipment used in the analysis.

4.5 EPA Method 1315 Data

EPA Method 1315 was performed on control and ash-amended concrete and mortar specimens. Results are shown in appendixes B and C, where the mass-release data (mg/m^2 as a function of time) are plotted for detected elements; elements that did not manifest concentrations above equipment detection limits over the entire 63-day testing interval are not displayed. Note that the GCTL for aluminum is not a health-based risk concentration. Method 1315 gives an indication of element leaching in monolithic (not crushed) samples, and in these tests more elements were released in the control concrete than in the ash-amended concrete. Furthermore, chromium concentrations are all much lower than those measured by SPLP. This trend is consistent across constituents of potential concern, and many elements analyzed showed concentrations below equipment detection limits.

4.6 EPA Method 1316 Leaching Characterization

EPA Method 1316 was used to characterize element leaching as a function of liquid-to-solid ratio at the natural pH of the material. Tables 4.8, 4.9, 4.10, and 4.11 show EPA Method 1316 results for cement products created with control and ash-amended cement. The groundwater cleanup target levels are displayed in the final column in each table; see the SPLP discussion in section 4.4 as relates to the applicability of comparing these results to the GCTL.

Eluate concentrations at low liquid-to-solid ratios give insights into pore solution composition of low permeability materials such as a crushed concrete specimen. However, there are a wide variety of end uses for concrete and mortar samples that could encompass the whole range of liquid-to-solid ratios tested; therefore, liquid-to-solid ratios of 0.5-10.0 were tested to give a full profile of leaching as a function of liquid-to-solid ratio for all cement products. The data for a liquid-to-solid ratio of 0.5 will be provided at a later date, as multiple analytical procedures require that multiple samples be tested at a later date.

Table 4.8. 1316 for crushed control cement mortar samples

Control cement mortar 1316	*Leaching at liquid/solid ratio (mg/L)*					
	0.5	**1.0**	**2.0**	**5.0**	**10.0**	**GCTL**
Extract pH	12.68	12.44	12.44	12.32	12.51	
Aluminum	—	0.994	0.903	1.64	0.953	0.200
Arsenic	—	0.00640	< 0.004	< 0.004	< 0.004	0.01
Boron	—	0.00580	0.00240	0.00680	0.00400	1.40
Barium	—	5.07	3.86	2.33	1.92	2.00
Beryllium	—	< 0.001	< 0.001	< 0.001	< 0.001	0.004
Calcium	—	704	615	587	845	—
Cadmium	—	< 0.001	< 0.001	< 0.001	< 0.001	0.005
Cobalt	—	0.0432	0.0254	0.0120	0.00840	0.140
Chromium	—	0.0674	0.0478	0.0444	0.0412	0.1
Copper	—	0.0258	0.0166	0.0266	0.0112	1.0
Iron	—	0.559	0.573	1.15	0.576	0.300
Potassium	—	513	196	81.5	56.3	—
Magnesium	—	0.822	0.846	1.04	0.811	—
Manganese	—	0.0126	0.0130	0.0244	0.0132	0.0500
Molybdenum	—	0.0398	0.0296	0.0244	0.0258	0.035
Sodium	—	205	79.6	31.4	21.3	160
Nickel	—	0.01120	0.00580	0.00480	0.00280	0.100
Lead	—	0.0108	0.00780	0.0242	0.00640	0.015
Antimony	—	< 0.003	0.00360	< 0.003	< 0.003	0.006
Selenium	—	0.00660	0.00320	0.00660	0.00600	0.0500
Tin	—	0.0230	0.00860	0.00280	0.00280	4.2
Strontium	—	36.2	21.6	10.6	7.85	4.2
Titanium	—	0.0360	0.0378	0.0754	0.0346	—
Vanadium	—	< 0.001	< 0.001	0.00320	0.00120	0.0490
Zinc	—	0.0236	0.0228	0.463	0.0240	5.0

Table 4.9. 1316 for crushed bottom ash-amended cement mortar samples

Bottom ash-amended cement mortar 1316	*Leaching at liquid/solid ratio (mg/L)*					
	0.5	**1.0**	**2.0**	**5.0**	**10.0**	**GCTL**
Extract pH	12.68	12.44	12.44	12.32	12.51	
Aluminum	—	1.03	0.889	0.879	0.897	0.200
Arsenic	—	< 0.004	< 0.004	< 0.004	< 0.004	0.01
Boron	—	< 0.01	< 0.01	< 0.01	< 0.01	1.40
Barium	—	3.27	2.22	1.81	0.924	2.00
Beryllium	—	< 0.001	< 0.001	< 0.001	< 0.001	0.004
Calcium	—	696	493	609	620	—
Cadmium	—	< 0.002	< 0.002	< 0.002	< 0.002	0.005
Cobalt	—	0.0786	0.0478	0.0278	0.0118	0.140
Chromium	—	0.121	0.0742	0.0784	0.0620	0.1
Copper	—	0.0428	0.0386	0.0234	0.0138	1.0
Iron	—	0.652	0.526	0.540	0.593	0.300
Potassium	—	419	199	84.1	35.4	—
Magnesium	—	0.806	0.877	0.882	0.890	—
Manganese	—	0.0126	0.0134	0.0146	0.0138	0.0500
Molybdenum	—	0.00780	0.00420	0.00480	0.00460	0.035
Sodium	—	240	128	48.4	19.1	160
Nickel	—	0.00140	0.00180	0.00220	0.00100	0.100
Lead	—	0.0132	0.0168	0.0158	0.0118	0.015
Antimony	—	0.00320	< 0.003	< 0.003	< 0.003	0.006
Selenium	—	0.00700	0.00260	0.00360	0.00620	0.0500
Tin	—	0.00220	0.00280	0.00260	0.00200	4.2
Strontium	—	41.8	25.1	15.9	6.48	4.2
Titanium	—	0.0338	0.0398	0.0402	0.0396	—
Vanadium	—	< 0.001	< 0.001	< 0.001	< 0.001	0.0490
Zinc	—	0.0268	12.0	0.204	0.0240	5.0

Table 4.10. 1316 for Crushed control cement concrete samples

Control cement concrete 1316	*Leaching at liquid/solid ratio (mg/L)*					
	0.5	**1.0**	**2.0**	**5.0**	**10.0**	**GCTL**
Extract pH	11.91	11.86	11.84	11.77	11.77	
Aluminum	1.02	0.742	0.698	0.811	0.958	0.200
Arsenic	< 0.004	< 0.004	< 0.004	0.109	0.0190	0.01
Boron	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.40
Barium	4.45	1.76	2.20	1.21	0.873	2.00
Beryllium	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.004
Calcium	894	429	545	491	580	—
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.005
Cobalt	0.0426	0.0110	0.0126	0.00580	0.00360	0.140
Chromium	0.0704	0.0274	0.0300	0.0290	0.0434	0.1
Copper	0.0174	0.00400	0.00400	0.0118	0.0116	1.0
Iron	0.689	0.566	0.572	0.662	0.667	0.300
Potassium	459	88.0	62.6	19.9	13.1	—
Magnesium	1.02	0.848	0.786	0.870	0.964	—
Manganese	0.0164	0.0134	0.0130	0.0138	0.0152	0.0500
Molybdenum	0.0466	0.0202	0.0192	0.0208	0.0268	0.035
Sodium	218	41.5	32.1	9.60	5.82	160
Nickel	< 0.001	< 0.001	< 0.001	0.00180	0.00220	0.100
Lead	0.00920	0.00580	0.00720	0.00740	0.00880	0.015
Antimony	0.00380	0.00500	0.00300	0.0130	0.00380	0.006
Selenium	0.00500	0.00440	0.00180	0.0112	0.00280	0.0500
Tin	0.00920	< 0.002	0.00340	0.270	0.0622	4.2
Strontium	45.0	14.0	14.0	5.86	3.71	4.2
Titanium	0.0390	0.0358	0.0336	0.0460	0.0450	—
Vanadium	< 0.001	< 0.001	< 0.001	0.00140	0.00160	0.0490
Zinc	0.00920	0.00260	0.00220	0.0246	0.0262	5.0

Table 4.11. 1316 for crushed bottom ash-amended cement concrete samples

Bottom ash-amended cement concrete 1316	*Leaching at liquid/solid ratio (mg/L)*					
	0.5	**1.0**	**2.0**	**5.0**	**10.0**	**GCTL**
Extract pH	12.36	11.96	12.01	12.08	11.84	
Aluminum	1.61	1.60	1.56	1.54	1.62	0.200
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	0.01
Boron	0.00870	0.0213	0.0150	0.0114	0.00840	1.40
Barium	3.85	2.86	2.82	1.86	1.16	2.00
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004
Calcium	873	840	969	980	1030	—
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.005
Cobalt	0.115	0.0582	0.0468	0.0249	0.0135	0.140
Chromium	0.195	0.129	0.126	0.132	0.135	0.1
Copper	0.0753	0.0414	0.0288	0.0192	0.0150	1.0
Iron	1.33	1.11	1.14	1.06	1.10	0.300
Potassium	554	250	143	53.9	27.9	—
Magnesium	1.48	1.55	1.53	1.53	1.54	—
Manganese	0.0255	0.0252	0.0246	0.0249	0.0249	0.0500
Molybdenum	0.0156	0.0105	0.0108	0.00960	0.0102	0.035
Sodium	359	159	91.5	35.8	19.2	160
Nickel	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.100
Lead	0.0150	0.0105	0.0102	0.0117	0.00930	0.015
Antimony	0.00420	0.0129	0.00720	0.00600	0.00870	0.006
Selenium	0.00750	0.0123	0.0153	0.0174	0.0111	0.0500
Tin	0.00690	0.00720	0.00660	0.00750	0.00720	4.2
Strontium	62.4	41.2	31.6	15.6	8.95	4.2
Titanium	0.101	0.101	0.0993	0.101	0.0993	—
Vanadium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.0490
Zinc	0.0336	0.0270	0.0141	0.0198	0.0189	5.0

From these results we can see a few exceedances for groundwater cleanup target levels across all samples. In the control mortar specimens, there is a slight exceedance of the groundwater cleanup target level for molybdenum at a liquid-to-solid ratio of 1.0 (0.0398 mg/L vs 0.035 mg/L); recall that control mortar SPLP samples also showed molybdenum exceedances on the same order of magnitude. At a liquid-to-solid ratio of 5.0, there are also lead exceedances (0.0242 mg/L vs 0.015 mg/L). Control mortar specimens showed no such exceedances when tested with the SPLP. The aluminum groundwater cleanup target level was exceeded in *all* samples (both control and ash-amended samples) at *all* liquid-to-solid ratios.

Ash-amended mortar specimens at a liquid-to-solid ratio of 1.0 had a slight exceedance of the GCTL for chromium (0.121 mg/L vs the GCTL of 0.1 mg/L); this concentration was very similar to the SPLP chromium concentration reported for the same sample. At a liquid-to-solid ratio of 2.0 and 5.0, the GCTL for lead was exceeded slightly (0.0168 mg/L and 0.0158 mg/L respectively vs. The GCTL of 0.015 mg/L). At a liquid-to-solid ratio of 2.0, a spike in the zinc concentration of 12.0 mg/L was observed, in excess of the 5.0 mg/L groundwater cleanup target level.

Control cement concrete specimens saw a slight molybdenum and antimony exceedance at a liquid-to-solid ratio of 5.0 (0.0466 mg/L vs 0.035 mg/L) and (0.0130 mg/L vs 0.006 mg/L) respectively. Molybdenum exceedances are consistent with the SPLP results as well, though antimony exceedances found in EPA Method 1316 were unexpected based upon SPLP extract concentrations.

In the ash-amended cement concrete samples, chromium exceeded the regulatory limit of 0.1 mg/L across all liquid-to-solid ratios tested (consistent with SPLP results). Antimony concentrations at liquid-to-solid ratios of 1.0, 2.0 and 10.0 all showed slight exceedances of the GCTL for antimony of 0.006 mg/L (0.0129 mg/L, 0.0072 mg/L, and 0.00870 mg/L).

Overall, control and ash-amended cement products behaved similarly in regards to leaching as a function of liquid-to-solid ratio. However, consistent with other leaching data presented, chromium was slightly elevated in ash-amended cement products, but only exceeded GCTL metrics slightly, similar to SPLP results for the same materials. EPA Method 1315 data indicated that early-age chromium leaching in monolithic samples is not issue. The slight lead exceedances found in ash-amended cement products were also found in the control products at the same magnitude. Also, the slight antimony exceedances found in ash-amended cement products were also found in the control products at the same magnitude. There was a high zinc concentration found at a single liquid-to-solid ratio extraction of ash-amended mortar specimens, this is inconsistent with the other leaching data, and could be due to a sample outlier. Control cement products had a similar elevated molybdenum concentration seen in other leaching data. Elevated molybdenum concentrations were not seen in ash-amended products.

4.7 EPA Method 1313 Leaching Characterization

EPA Method 1313 was used to characterize the leaching of cement products across a range of pH values. Preliminary results for leaching as a function pH for select elements are displayed in tables 4.12, 4.13, 4.14, and 4.15.

Table 4.12. 1313 for crushed control cement mortar specimens

Control cement mortar 1313	*pH control point*					
	12	**10**	**9**	**7**	**6**	**5**
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	0.00575	0.00800
Chromium	0.0831	1.25	1.38	2.02	0.735	1.83
Copper	< 0.002	< 0.002	< 0.002	< 0.002	0.0648	0.0700
Molybdenum	0.0687	0.217	0.216	0.486	0.216	0.0290
Lead	0.0112	<0.004	< 0.004	0.0124	0.0278	0.0300
Antimony	0.00320	0.0156	0.0195	0.0224	0.00625	0.0170
Zinc	0.0326	< 0.001	< 0.001	0.0202	2.54	4.02

Table 4.13. 1313 for crushed bottom ash-amended cement mortar specimens

Bottom ash-amended cement mortar 1313	*pH control point*				
	12	**11**	**10**	**7**	**5**
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Chromium	0.0855	0.790	2.51	2.02	1.28
Copper	< 0.002	0.0105	0.00720	< 0.002	0.723
Molybdenum	0.0553	0.0336	0.0507	0.486	0.00960
Lead	0.0120	< 0.004	< 0.004	0.0116	< 0.004
Antimony	0.00520	0.00780	0.0314	0.0224	0.0168
Zinc	0.0292	< 0.001	< 0.001	0.547	7.55

Table 4.14. 1313 for crushed control cement concrete specimens

Control cement concrete 1313	*pH control point*						
	12	**11**	**10**	**9**	**7**	**6**	**5**
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	0.0118	0.0130
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Chromium	0.0640	0.341	0.536	1.38	0.316	0.269	0.226
Copper	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.115	0.175
Molybdenum	0.0373	0.208	0.200	0.216	0.0936	0.179	0.202
Lead	0.00487	0.00650	0.00600	< 0.004	0.00920	0.0263	0.0365
Antimony	0.00593	0.00610	0.00950	0.0195	0.00540	0.00900	0.00300
Zinc	0.00513	0.00200	0.00220	< 0.001	0.350	1.12	2.13

Table 4.15. 1313 for crushed bottom ash-amended cement concrete specimens

Bottom ash-amended cement concrete 1313	*pH control point*						
	12	**11**	**10**	**9**	**7**	**6**	**5**
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Chromium	0.149	0.404	1.29	1.75	0.684	0.982	0.243
Copper	< 0.002	< 0.002	0.00240	0.00480	0.0708	0.0753	0.327
Molybdenum	0.0107	0.0266	0.0492	0.0582	0.0138	0.0335	0.0220
Lead	0.00708	0.00900	< 0.004	< 0.004	0.00740	0.0265	0.0360
Antimony	0.00680	0.00680	0.0231	0.0288	0.0116	0.0118	< 0.003
Zinc	0.00808	< 0.001	< 0.001	< 0.001	2.09	0.644	3.22

The data indicate the same leaching trend for control and ash-amended cement products seen across most of the leaching data. Control specimens showed elevated levels of molybdenum, often exceeding the GCTL benchmark, that ash-amended specimens did not indicate. However, the elevated chromium levels seen in ash-amended cement products are also shown in 1313 data; the data indicate that chromium may be a concerning analyte across all pH ranges, but the elevated concentrations are lower at high pH. It is important to consider the final pH of the application, and an in-use scenario for concrete is likely to be at a higher pH. Lead concentrations in both control and ash-amended specimens exceed GCTLs at low pH, which is consistent with known pH-dependent lead leaching trends. Both control and ash- amended products also had similar antimony concentrations as a function of pH.

4.8 Performance Testing

Isothermal calorimetry results are presented in figures 4.2 and 4.3. The results indicate that ash-amended cement may see increased heat development and reactivity when compared to control cement. These data may also explain the faster time of set values for ash-amended mortar discussed later in this section.

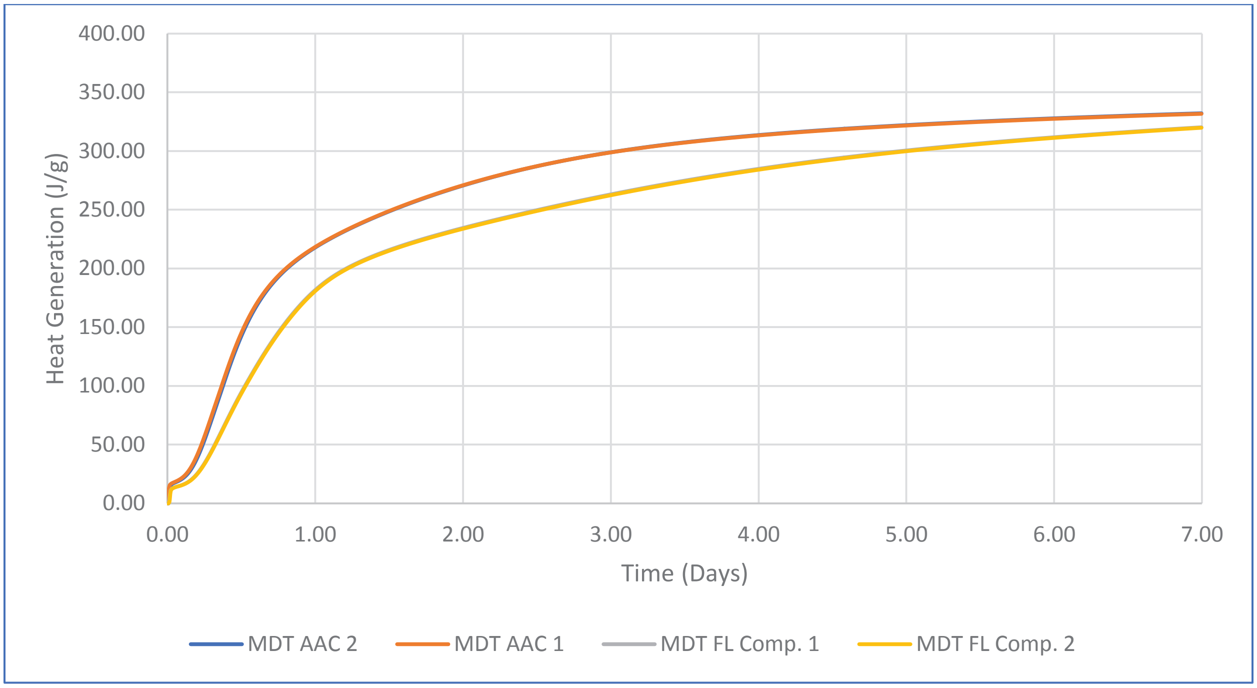

Figure 4.2. Isothermal calorimetry results

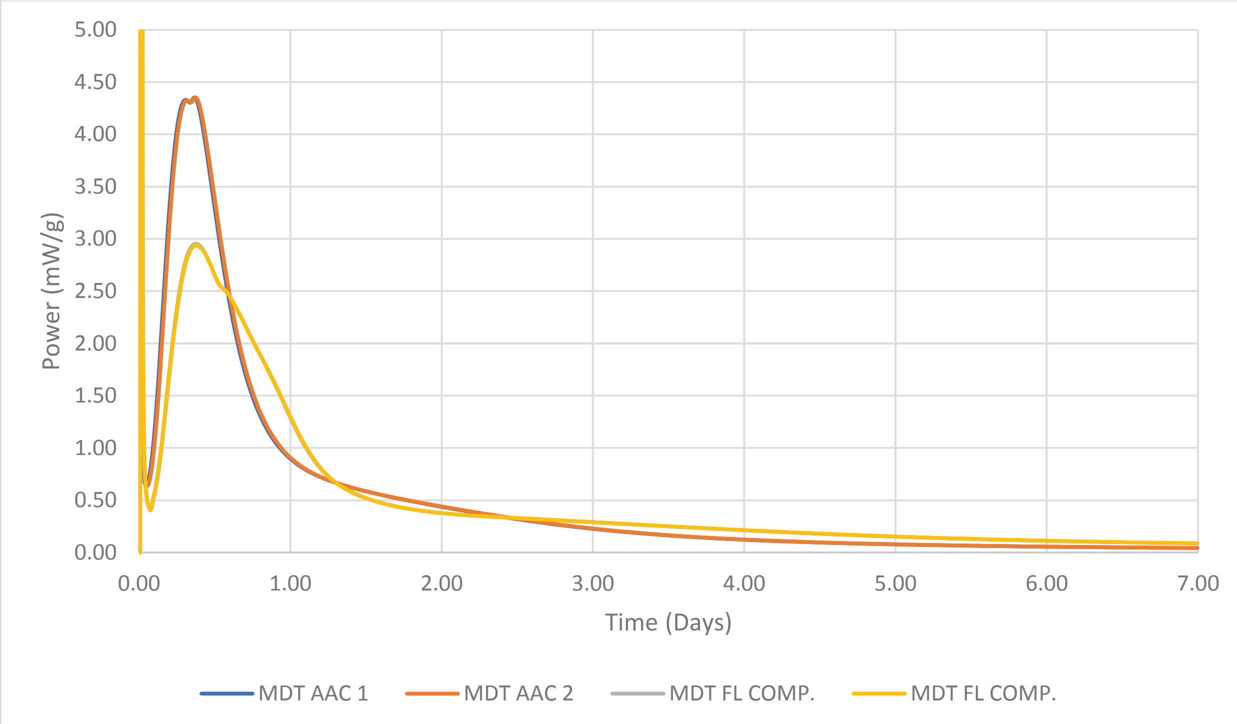

Figure 4.3. Isothermal calorimetry results

Figure 4.4 shows the results of the mortar compressive strength tests. The results indicate that the ultimate (28-day) mortar compressive strength for the control cement is approximately 10% stronger than the ash-amended cement mortar, but this difference lies within the acceptable precision limits for the dual operator test methods.

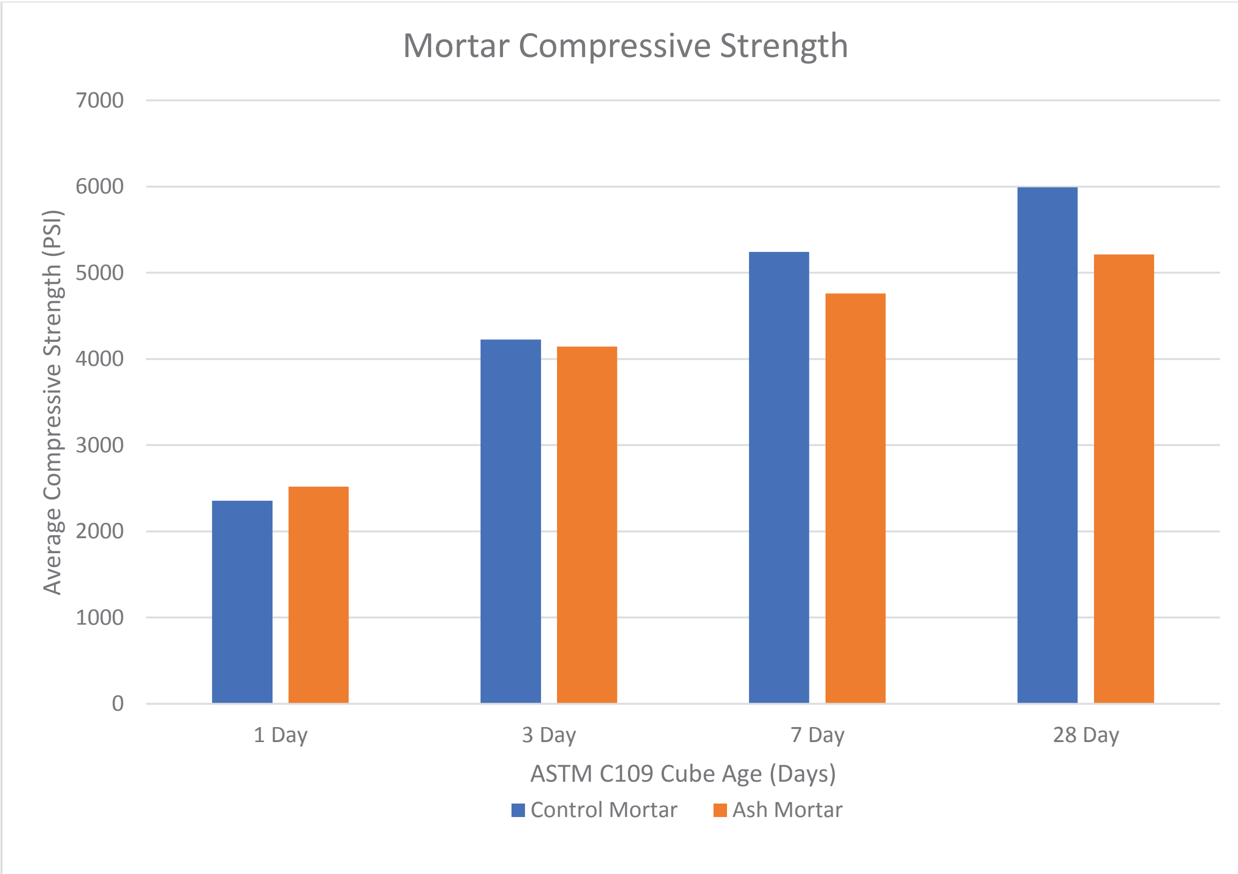

Figure 4.4. Evolution of mortar compressive strength over time

Figures 4.5 and 4.6 show the time of set measured for both the control mortar and the ash-amended mortar. The ash-amended cement mortar reached final set (4,000 PSI) more quickly than the Florida composite cement mortar. This may indicate increased reactivity in the ash-amended cement. It is difficult to determine reasons for faster setting without extensive testing, this data is consistent with the increased reactivity and heat development observed in the isothermal calorimetry testing.

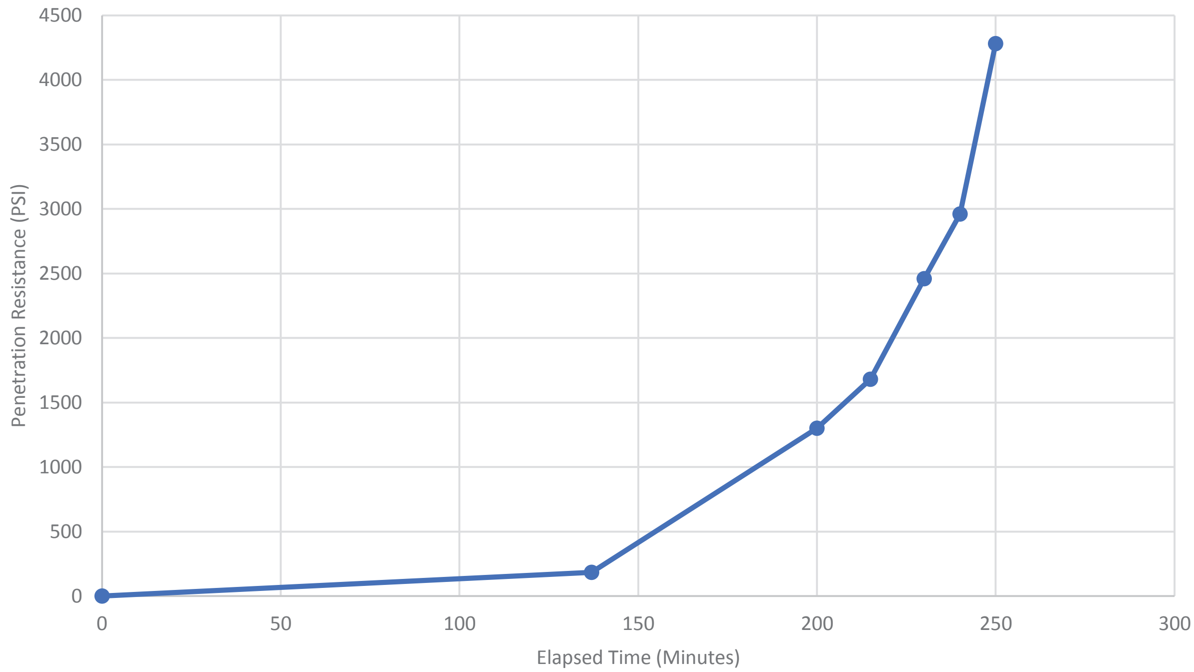

Figure 4.5. Mortar time of set results for ash-amended mortar

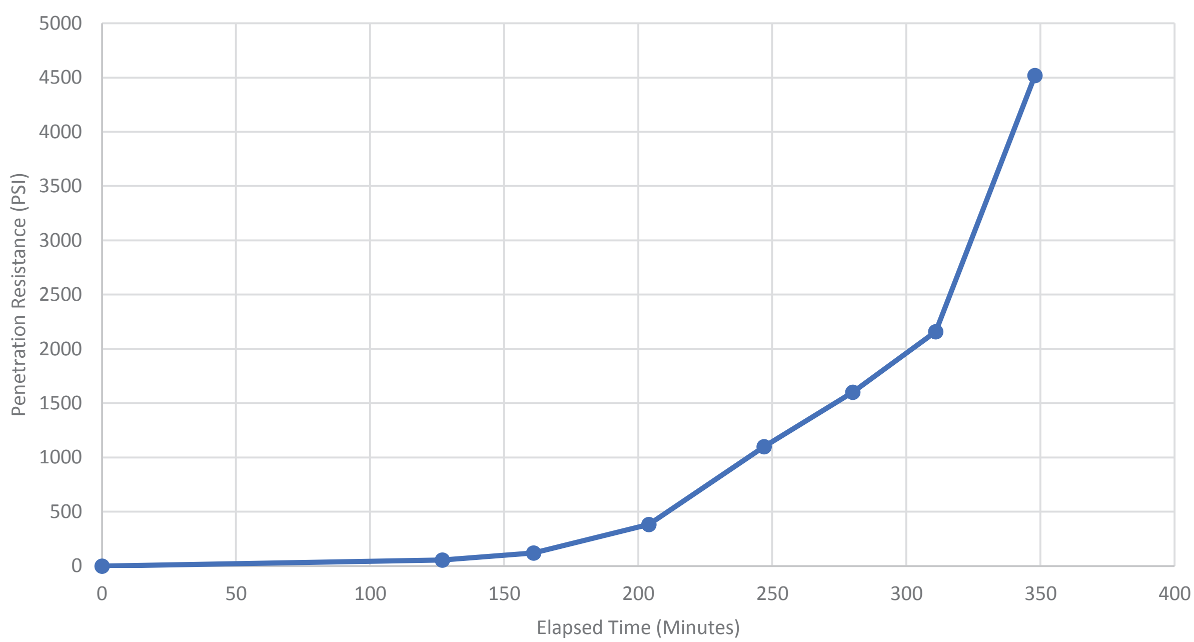

Figure 4.6. Mortar time of set results for control mortar

5.0 Risk Assessment

Extensive laboratory testing, including total concentrations, environmental batch leaching, monolithic tank leaching, and performance testing was performed in order to evaluate differences between control cement products and cement products created with cement amended with Miami-Dade County RRF bottom ash as an alternative kiln feed. Ash-amended cement, with Miami-Dade bottom ash at approximately 2.8% replacement of total kiln feed, was created in an industrial scale Titan cement kiln and brought back to University of Florida labs for analysis. Control and ash-amended cement samples were characterized to determine whether any significant differences existed between the two cements. Any elements with elevated concentrations in the waste-to-energy bottom ash were expected to be diluted, and this was in fact shown to be the case. Lead, for example, was shown to exceed commercial target levels for clean soil in the waste-to-energy bottom ash (27.5 mg/kg), but in the ash-amended cement, lead concentration fell back to approximately 20% of the bottom ash (5.20 mg/kg). Arsenic is another element known to be elevated in WTE ash, but the tests here show that the arsenic concentration in the control cement was actually much higher than in the ash-amended cement (13.7 mg/kg control compared to 5.20 mg/kg ash-amended cement). This further supports the hypothesis that at the levels in which ash was added, it has a minimal effect on overall cement concentrations.

Preliminary data suggests that there are no significant environmental concerns with RRF bottom ash-amended cement when compared to control cement. The totals suggest that there is no *excess* direct exposure risk associated with ash-amended cement products when compared to control cement products. SPLP and other batch leaching results indicate that ash-amended cement products may have slightly elevated leached chromium concentrations when compared to control cement products. However, this concentration is approximately within 10% of the risk-based groundwater cleanup target level (the comparative metric for leachability used in this study) for chromium. Control cement products showed elevated levels of molybdenum not seen in ash-amended cement products. Preliminary EPA Method 1315 mass-release curves indicate that mass release of chromium in monolithic ash-amended cement products is very low and may thus rule out issues associated with chromium leaching.

From a performance standpoint, ash-amended cement products are very similar to control cement products. XRD analysis shows that the two cements have a very similar mineralogical composition. Isothermal calorimetry data indicates that the heat of hydration of both cements is very similar. Time of set indicates that mortar created with bottom ash-amended cement may set faster than the control cement mortar. Mortar compressive strength indicates that the mortar cube strength of ash-amended cement mortars is weaker but well within the dual operator precision statement of the test method; thus it cannot be reliably attributed to any differences in cement performance.

Overall, data suggests that there is no excess environmental risk associated with amending cement with Miami-Dade bottom ash, and that the cement also behaves similarly in regards to performance. The cement created in the Titan test burn, using approximately 3% total replacement of raw kiln feed with Miami-Dade bottom ash, did not exhibit any environmental attributes that suggest it would represent any additional risk when compared to typical cement and cement products. Elevated total concentrations seen in bottom ash were significantly diluted when integrated into cement. Chromium leaching was slightly elevated in ash-amended specimens subjected to batch leaching tests, but monolithic leaching tests indicate that chromium mass release for ash-amended specimens is actually extremely low. Any other leaching issues with ash-amended cement products were also leaching issues for control cement products at an equal or greater magnitude. There were no significant differences in performance. Based on this information, it is apparent that bottom ash can be effectively used as a replacement kiln feed at the mass percentage specified without any adverse effects on human health or the environment.

6.0 South Florida Materials Market Analysis

As the global transition from linear to circular waste-utilization models continues to gain steam, recovery and utilization of WTE ash as a cement kiln replacement constitutes an ever-more-crucial advancement in the conservation of resources within waste management. Miami-Dade County RRF processes approximately 2,592 tons of municipal solid waste through its incinerator [15]. An assumption of 15% by weight of WTE ash is produced in the incineration process, which results in approximately 142,000 tons of WTE ash produced per year [16]. The current protocol for disposal is to transport the WTE ash to an ash monofill located near the RRF [17]. Titan Pennsuco produces 2.2 million tons of clinker per year; factoring in the determined 3% ash kiln feed replacement, Titan Pennsuco could utilize approximately 66,000 tons of WTE ash annually [18]. Providing the 66,000 tons of WTE ash to Titan Pennsuco for replacement kiln feed would produce revenue as well as extend the life of the ash monofill. As for Titan Pennsuco, purchasing or simply receiving a lower-cost alternative to its current kiln feed would be beneficial as well. Regarding the 76,000 tons of WTE ash remaining, another 30,000 tons of WTE ash could be utilized as kiln feed replacement at other cement plants in the Miami area, resulting in additional opportunities for Miami-Dade County to recycle its ash. A separate cement plant in the Miami area produces approximately 1 million tons of clinker per year [19] and is located approximately 9 miles from the Miami-Dade RRF (see figure 6.1).

Further understanding of WTE ash and clinker production in South Florida draws attention to the excess amount of WTE ash that can be utilized as kiln feed replacement. Excluding RRF, there are four WTE plants located in South Florida: Lee County Resource Recovery Facility, Wheelabrator South Broward, Palm Beach Renewable Energy Facility (REF) 1, and Palm Beach REF 2. Referring to table 6.1, the amount of WTE ash produced in South Florida totals approximately 1,086,240 tons annually (including Miami-Dade RRF) [20]. Approximately 96,000 tons of that ash could be repurposed as kiln feed replacement for the two existing cement plants in the Miami area.

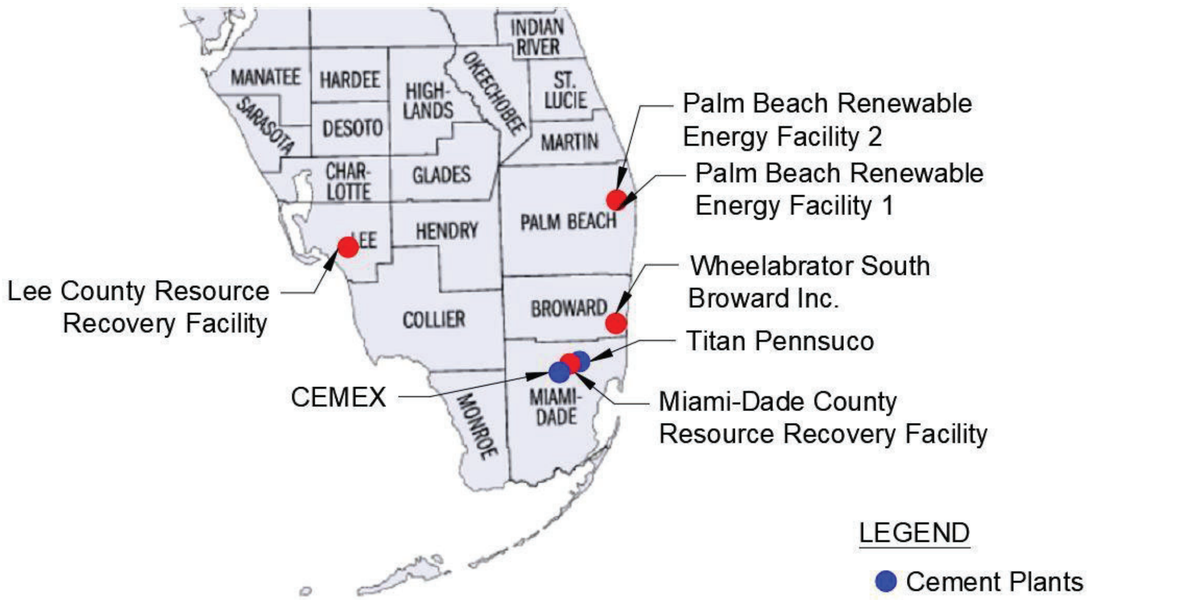

Figure 6.1. Current market for WTE ash and cement kilns in South Florida

Table 6.1. Materials analysis for South Florida

Facility	*Location*	*MSW capacity (TPD)*	*% WTE ash*	*Ash produced (TPD)*
Miami-Dade RRF	Miami	2,592	15	389
Lee County RRF	Fort Myers	1,836	33	606
Palm Beach REF 1	West Palm Beach	1,650	15	248
Palm Beach REF 2	West Palm Beach	3,000	33	990
Wheelabrator South Broward	Fort Lauderdale	2,250	33	743
			Total ash produced (TPD)	2,976
			Total ash produced annually	1,086,240

7.0 Conclusions and Recommendations

Analysis of the cement and cement products manufactured with Miami-Dade Resource Recovery Facility's bottom ash concluded that at the determined kiln feed replacement value of 2.8% there is no *excess* leaching risk when compared to the control cement. Also, performance characterization of both control and ash-amended cements concluded that the two products behave similarly in regards to mineralogical composition and heat of hydration. Testing of the mortar compressive strength also indicated that the ash-amended cement mortars were not significantly weaker than the control cement mortar. Data supports the recommendation that WTE ash be incorporated into the manufacture of cement at the Titan Pennsuco facility at the given replacement percentage. Given Titan's annual clinker production and the amount of MSW incinerated at the Miami-Dade Resource Recovery Facility, approximately 66,000 tons of ash (35% of total ash production) can be diverted from the ash monofill at the determined kiln replacement percentage of 2.8%. The remaining 123,000 tons of WTE ash could potentially be diverted to other cement plants in the area to acquire additional recycling opportunities and extend the life of the monofill.

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Appendix A: Total Concentrations, All Specimens

Table A-1. Total concentrations for control cement products, aluminum-iron

	Sub-sample	*Total concentration (mg/kg)*										
		Al	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**
Control clinker	1	24,300	3.55	57.9	190	1.90	425,000	1.60	9.30	183	170	23,200
	2	23,200	3.45	56.0	181	1.90	407,000	1.50	9.15	170	161	22,100
	3	22,600	3.15	56.9	182	1.80	419,000	1.60	8.90	193	165	22,600
	Avg	23,400	3.38	56.9	184	1.87	417,000	1.57	9.12	182	165	22,600
Control cement	1	23,800	12.6	60.5	281	1.50	422,000	2.35	10.1	98.2	151	19,600
	2	23,000	13.0	61.8	236	1.70	418,000	1.95	10.3	93.8	175	20,900
	3	28,100	15.4	71.3	311	1.80	491,000	2.85	11.8	118	184	23,000
	Avg	25,000	13.7	64.5	276	1.67	444,000	2.38	10.7	103	170	21,200
Control cement mortar	1	4,579	2.30	17.4	49.0	0.350	91,800	0.850	2.55	22.0	25.5	4,236
	2	6,210	4.25	22.2	62.4	0.450	117,150	1.20	3.25	29.4	39.3	5,765
	3	3,260	2.50	13.1	37.4	0.250	67,650	0.650	1.90	16.0	15.1	3,033
	Avg	4,683	3.02	17.6	49.6	0.350	92,200	0.900	2.57	22.4	26.6	4,345
Control cement concrete	1	6,970	5.90	19.1	76.6	0.500	146,000	1.00	3.60	31.0	54.0	6,400
	2	8,130	5.60	21.8	90.9	0.550	158,000	1.10	4.10	35.7	62.3	7,410
	3	7,400	5.45	20.9	74.1	0.500	149,000	0.80	3.65	31.3	62.2	7,340
	Avg	7,500	5.65	20.6	80.5	0.517	151,000	0.97	3.78	32.7	59.5	7,050
Residential soil cleanup target level		80,000	2.1	17,000	120	120	—	82	1,700	210*	150	53,000
Comm./ industrial soil cleanup target level		—	12	430,000	130,000	1,400	—	1,700	42,000	470*	89,000	—

*Hexavalent.

Table A-2. Total concentrations for control cement products, potassium-strontium

	Sub-sample	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr
		Total concentration (mg/kg)										
Control clinker	1	2,300	8,260	1170	4.00	883	12.0	1.30	3.85	2.50	2.00	883
	2	2,360	7,990	1120	3.45	861	11.0	1.55	3.20	3.10	1.85	858
	3	2,760	8,240	1220	3.50	843	10.9	2.35	5.25	2.75	1.85	883
	Avg	2,470	8,160	1170	3.65	862	11.3	1.73	4.10	2.78	1.90	875
Control cement	1	2,170	6,620	351	28.8	988	10.1	31.1	3.05	2.30	4.40	591
	2	2,500	6,290	344	29.7	1,170	11.5	31.8	3.40	3.20	4.80	595
	3	2,610	7,550	415	34.7	1,170	14.3	36.8	2.40	3.00	5.60	694
	Avg	2,430	6,820	370	31.0	1,110	12.0	33.2	2.95	2.83	4.93	627
Control cement mortar	1	409	1,333	85.0	8.60	692	0.500	7.60	1.50	0.550	1.95	161
	2	452	1,638	111	10.8	755	0.500	9.70	0.750	1.20	2.25	201
	3	224	1,087	63.0	6.80	504	0.500	6.05	1.05	1.32	1.30	125
	Avg	362	1,353	86.3	8.72	650	0.500	7.78	1.10	1.02	1.83	162
Control cement concrete	1	340	2,690	109	11.3	267	5.25	11.4	2.80	1.25	2.65	225
	2	377	3,020	125	12.7	275	4.10	13.6	1.80	2.00	2.70	241
	3	466	2,720	116	11.2	311	4.50	12.8	2.70	1.00	2.35	226
	Avg	394	2,810	117	11.7	284	4.62	12.6	2.43	1.42	2.57	231
Residential soil cleanup target level		—	—	3,500	440	—	340	400	27	440	47,000	52,000
Comm./ industrial soil cleanup target level		—	—	43,000	11,000	—	35,000	1,400	370	11,000	880,000	—

Table A-3. Total concentrations for control cement products, titanium-zinc

	Sub-sample	Total concentration (mg/kg) K	Mg	Mn
Control clinker	1	765	53.3	386
	2	738	50.1	372
	3	743	50.9	389
	Avg	748	51.4	382
Control cement	1	716	66.8	332
	2	734	71.2	348
	3	795	79.0	396
	Avg	748	72.3	358
Control cement mortar	1	235	15.7	0.50
	2	300	19.5	0.50
	3	175	11.7	0.50
	Avg	236	15.6	0.50
Control cement concrete	1	300	16.2	105
	2	346	19.9	123
	3	341	21.0	116
	Avg	329	19.0	115
Residential soil cleanup target level		—	67	26,000
Comm./ industrial soil cleanup target level		—	10,000	630,000

Table A-4. Total concentrations for ash-amended cement products, aluminum-iron

	Sub-sample	*Total concentration (mg/kg)*										
		Al	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**
Miami-Dade bottom ash	1	23,200	26.7	126	459	0.500	141,000	10.2	28.8	98.3	4,860	12,800
	2	99,400	33.5	100	356	0.500	123,000	9.85	12.4	91.5	1,130	13,600
	3	20,000	22.4	123	385	0.500	113,000	7.85	12.6	77.9	33,800	13,900
	Avg	47,500	27.5	116	400	0.500	126,000	9.30	17.9	89.2	13,200	13,400
Bottom ash amended clinker	1	16,800	5.45	64.9	166	1.20	358,000	1.75	8.85	121	175	19,600
	2	18,800	5.70	64.7	146	1.15	355,000	1.75	9.20	138	188	21,900
	3	21,100	6.20	70.1	175	1.30	400,000	2.10	10.0	153	205	23,700
	Avg	18,900	5.78	66.5	162	1.22	371,000	1.87	9.35	137	189	21,700
Bottom ash amended cement	1	19,800	5.30	68.7	175	1.10	414,000	2.25	9.85	150	208	22,400
	2	19,000	5.45	65.9	157	1.05	401,000	2.10	9.20	141	191	21,500
	3	19,700	5.50	68.8	167	1.10	415,000	2.35	9.70	150	206	22,300
	4	19,600	4.30	66.8	173	1.05	411,000	2.20	9.35	144	194	21,700
	5	20,200	5.60	70.0	183	1.15	420,000	2.35	9.80	150	206	22,400
	6	20,100	5.05	69.2	179	1.15	414,000	2.35	9.95	152	211	22,500
	Avg	19,700	5.20	68.2	172	1.10	413,000	2.27	9.64	148	203	22,100
Bottom ash amended cement mortar	1	5,475	1.55	25.9	48.3	0.400	120,300	1.30	3.05	45.1	48.3	6,390
	2	8,625	2.05	37.4	65.9	0.500	182,100	1.80	4.20	66.8	73.6	10,010
	3	5,305	1.40	24.4	46.2	0.350	115,050	1.30	2.90	43.7	46.2	6,220
	Avg	6,468	1.67	29.2	53.5	0.417	139,150	1.47	3.38	51.9	56.0	7,540
Bottom ash amended cement concrete	1	6,030	2.55	21.0	61.1	0.500	132,000	1.05	3.25	46.5	58.6	6,790
	2	6,000	2.20	20.75	47.4	0.500	134,000	1.05	3.15	46.1	59.1	6,750
	3	6,410	2.20	21.7	51.0	0.500	140,000	1.15	3.25	49.1	60.4	7,110
	Avg	6,150	2.32	21.2	53.2	0.500	135,000	1.08	3.22	47.2	59.3	6,880
Residential soil cleanup target level		80,000	2.1	17,000	120	120	—	82	1,700	210*	150	53,000
Comm./ industrial soil cleanup target level		—	12	430,000	130,000	1,400	—	1,700	42,000	470*	89,000	—

**Hexavalent.*

Table A-5. Total concentrations for ash-amended cement products, potassium-strontium

	Sub-sample	*Total concentration (mg/kg)*										
		K	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**
Miami-Dade bottom ash	1	3,120	7,130	454	5.75	9,270	33.8	440	7.45	1.00	4.80	317
	2	2,650	8,300	1,090	6.95	7,080	88.8	561	9.50	1.00	12.8	291
	3	2,380	5,990	353	5.25	7,630	117	373	9.70	1.00	1.30	281
	Avg	2,720	7,140	632	5.98	7,990	79.8	458	8.88	1.00	6.30	296
Bottom ash amended clinker	1	1,460	6,710	800	5.15	1,450	10.2	27.4	3.00	3.95	2.75	718
	2	1,090	6,770	813	5.60	1,190	10.9	21.9	4.40	1.00	2.80	734
	3	1,460	7,550	894	5.80	1,380	12.8	30.5	3.20	2.60	2.40	798
	Avg	1,340	7,010	836	5.52	1,340	11.3	26.6	3.53	2.52	2.65	750
Bottom ash amended cement	1	2,340	7,420	841	6.00	1,570	13.4	45.6	3.10	2.90	3.10	818
	2	2,370	7,200	796	5.15	1,490	11.9	38.6	3.70	2.65	2.45	784
	3	2,370	7,480	842	5.65	1,590	13.2	45.5	3.10	2.70	3.15	818
	4	2,300	7,490	811	5.40	1,520	12.2	41.9	3.65	3.85	3.15	793
	5	2,370	7,680	844	5.90	1,600	13.2	46.4	3.35	2.70	3.00	823
	6	2,280	7,440	847	6.15	1,540	13.8	46.5	3.75	3.40	2.80	823
	Avg	2,340	7,450	830	5.71	1,550	12.9	44.0	3.44	3.03	2.94	810
Bottom ash amended cement mortar	1	679	1,912	261	2.40	783	0.500	13.0	1.30	0.800	3.85	271
	2	959	2,502	384	3.00	1,308	0.500	17.5	1.10	1.25	3.05	386
	3	533	1,848	249	2.15	1,097	0.500	12.3	1.30	1.12	2.40	260
	Avg	723	2,087	298	2.52	1,063	0.500	14.2	1.23	1.06	3.10	306
Bottom ash amended cement concrete	1	395	3,140	247	2.50	372	5.30	14.2	2.30	1.80	3.40	259
	2	397	2,730	247	2.30	352	5.40	13.9	3.25	1.25	2.80	260
	3	373	2,870	260	2.40	324	4.90	15.0	2.55	1.10	3.15	272
	Avg	388	2,910	251	2.40	349	5.20	14.4	2.70	1.38	3.12	264
Residential soil cleanup target level		—	—	3,500	440	—	340	400	27	440	47,000	52,000
Comm./industrial soil cleanup target level		—	—	43,000	11,000	—	35,000	1,400	370	11,000	880,000	—

Table A-6. Total concentrations for ash-amended cement products, titanium-zinc

	Sub-sample	*Total concentration (mg/kg)*		
		Ti	**V**	**Zn**
Miami-Dade bottom ash	1	244	10.4	2,823
	2	1,110	17.2	1,523
	3	504	8.90	1,124
	Avg	619	12.2	1,823
Bottom ash amended clinker	1	605	50.8	435
	2	660	53.4	443
	3	712	58.3	498
	Avg	659	54.1	459
Bottom ash amended cement	1	830	61.1	503
	2	808	60.1	474
	3	831	62.1	496
	4	811	61.3	480
	5	809	62.5	498
	6	836	62.1	508
	Avg	820	61.5	493
Bottom ash amended cement mortar	1	316	19.3	0.50
	2	463	29.0	0.50
	3	301	18.8	0.50
	Avg	360	22.4	0.50
Bottom ash amended cement concrete	1	297	15.0	142
	2	298	14.8	139
	3	312	15.4	147
	Avg	302	15.1	143
Residential soil cleanup target level		—	67	26,000
Comm./industrial soil cleanup target level		—	10,000	630,000

Appendix B: EPA Method 1315 Mass Release, All Mortar Specimens Above Detection Limit

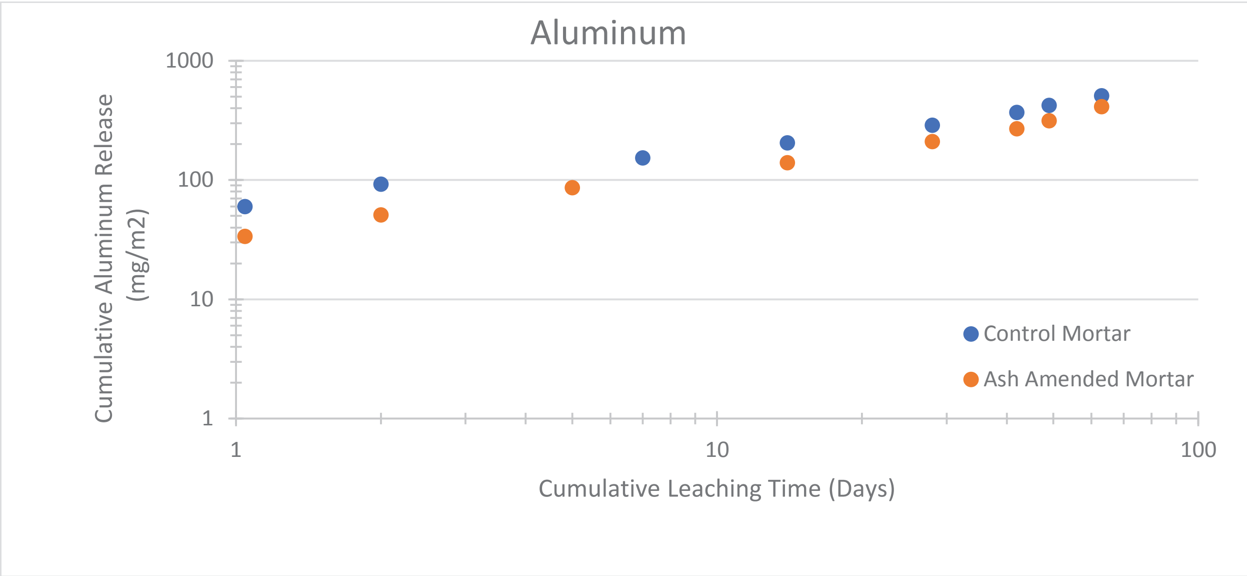


Figure B-1. Cumulative mass release for aluminum, EPA Method 1315, for control and ash-amended mortar specimens

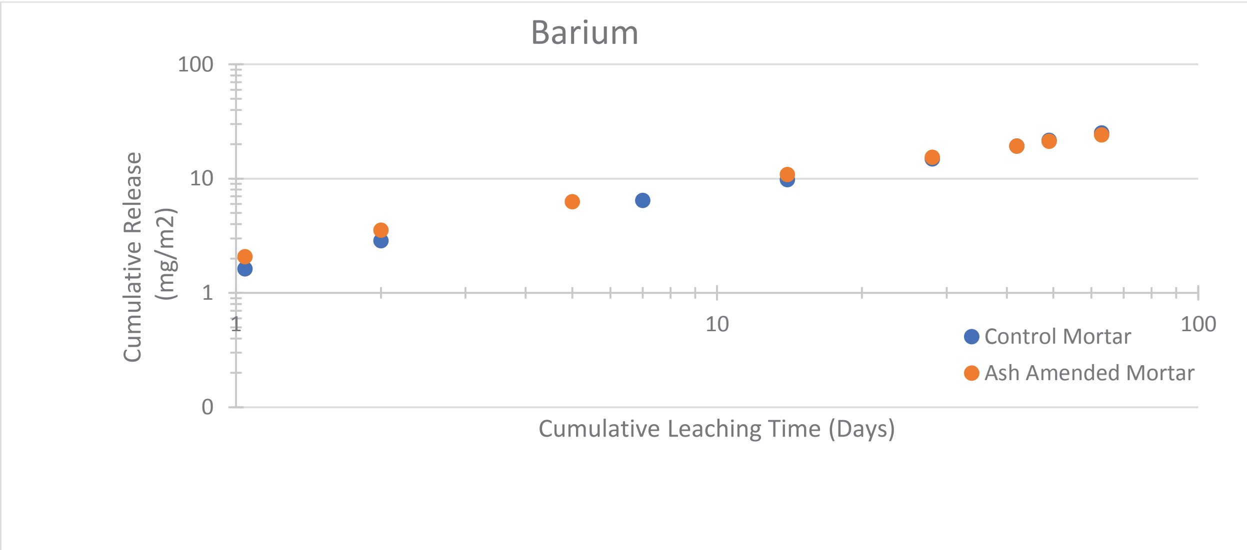


Figure B-2. Cumulative mass release for barium, EPA Method 1315, for control and ash-amended mortar specimens

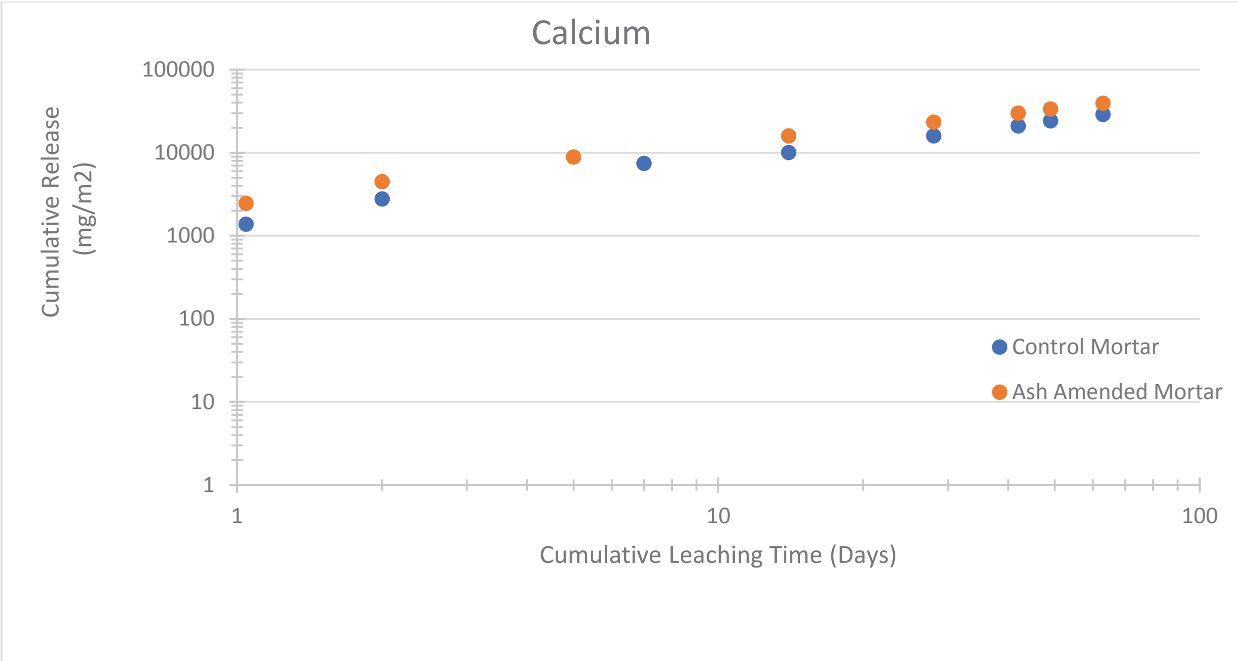


Figure B-3. Cumulative mass release for calcium, EPA Method 1315, for control and ash-amended mortar specimens

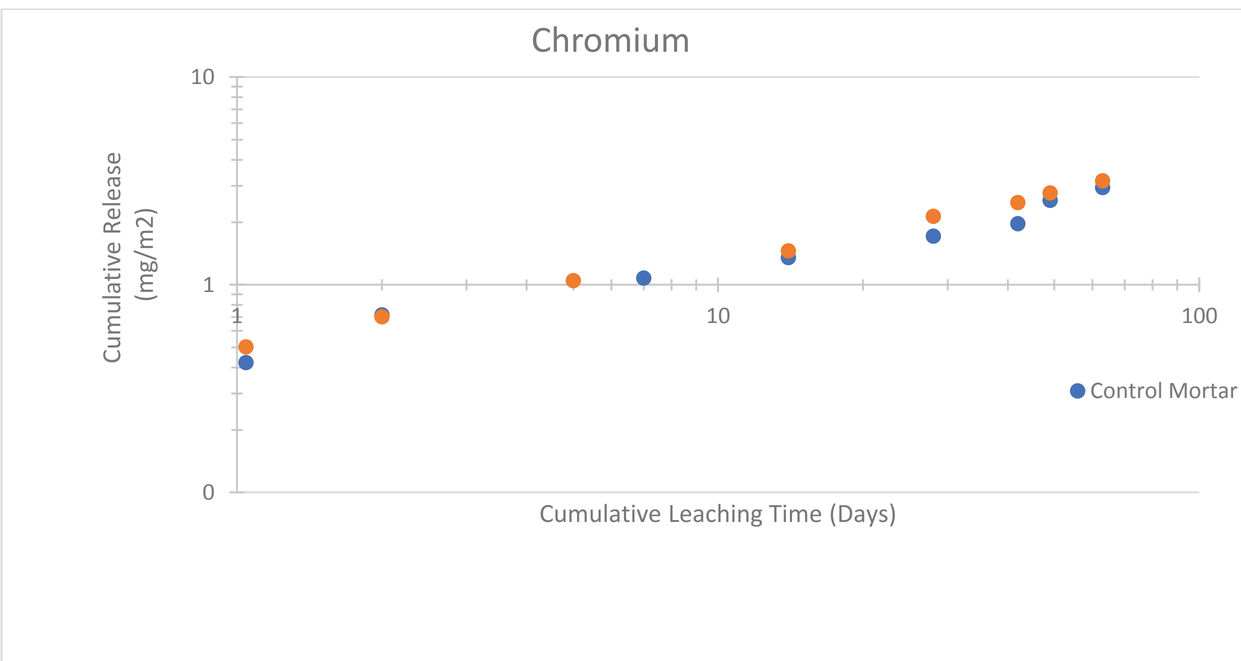


Figure B-4. Cumulative mass release for chromium, EPA Method 1315, for control and ash-amended mortar specimens

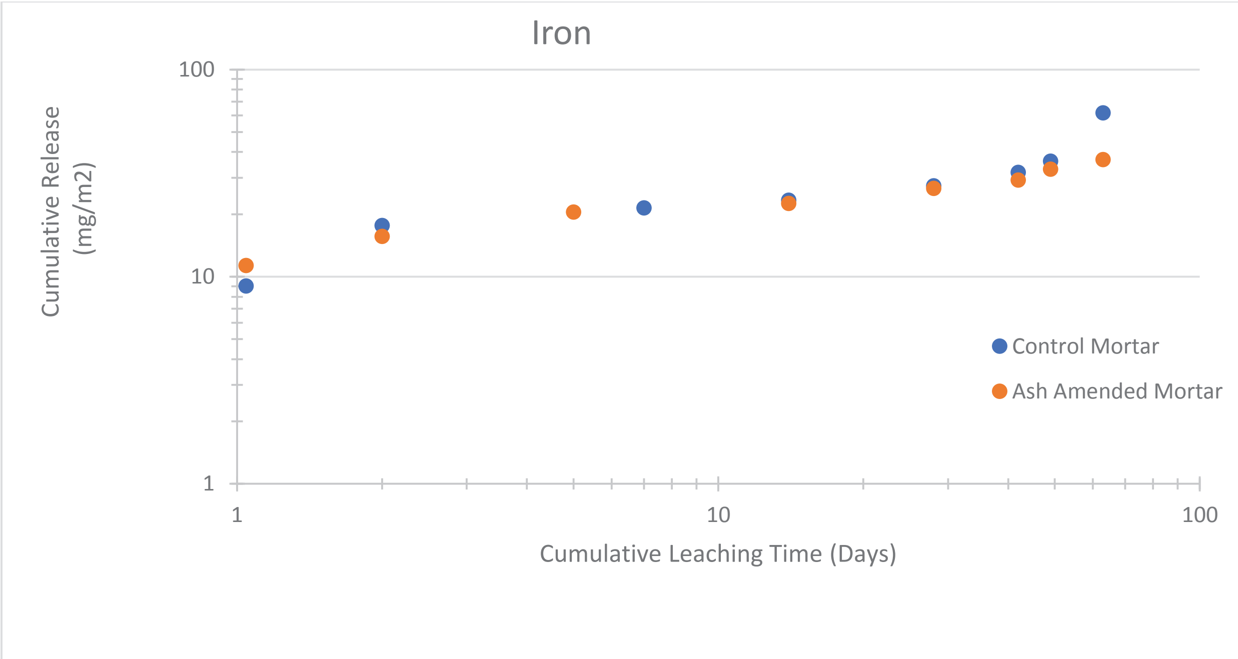


Figure B-5. Cumulative mass release for iron, EPA Method 1315, for control and ash-amended mortar specimens

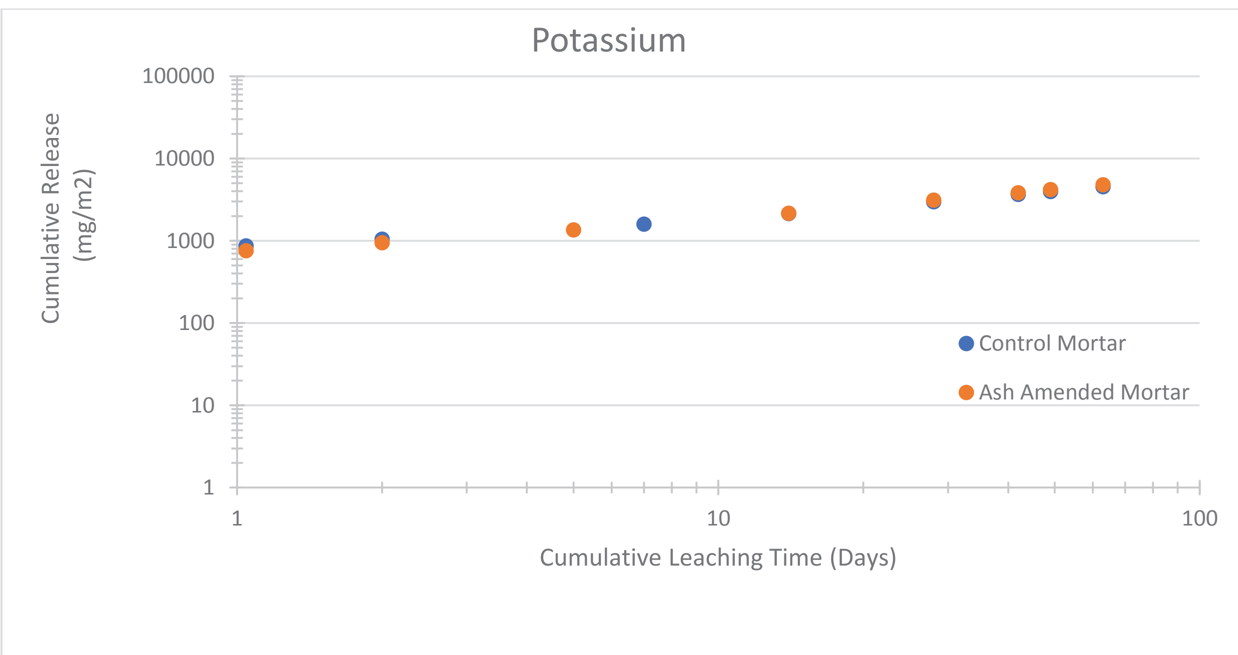


Figure B-6. Cumulative mass release for potassium, EPA Method 1315, for control and ash-amended mortar specimens

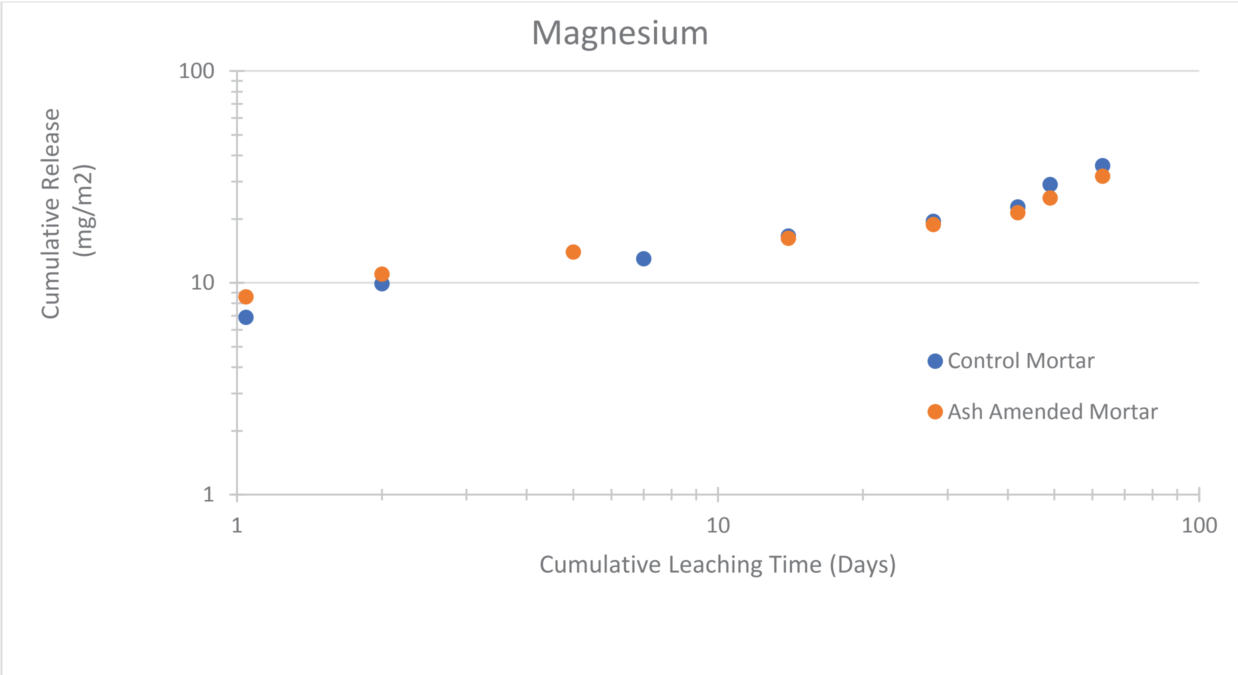


Figure B-7. Cumulative mass release for magnesium, EPA Method 1315, for control and ash-amended mortar specimens

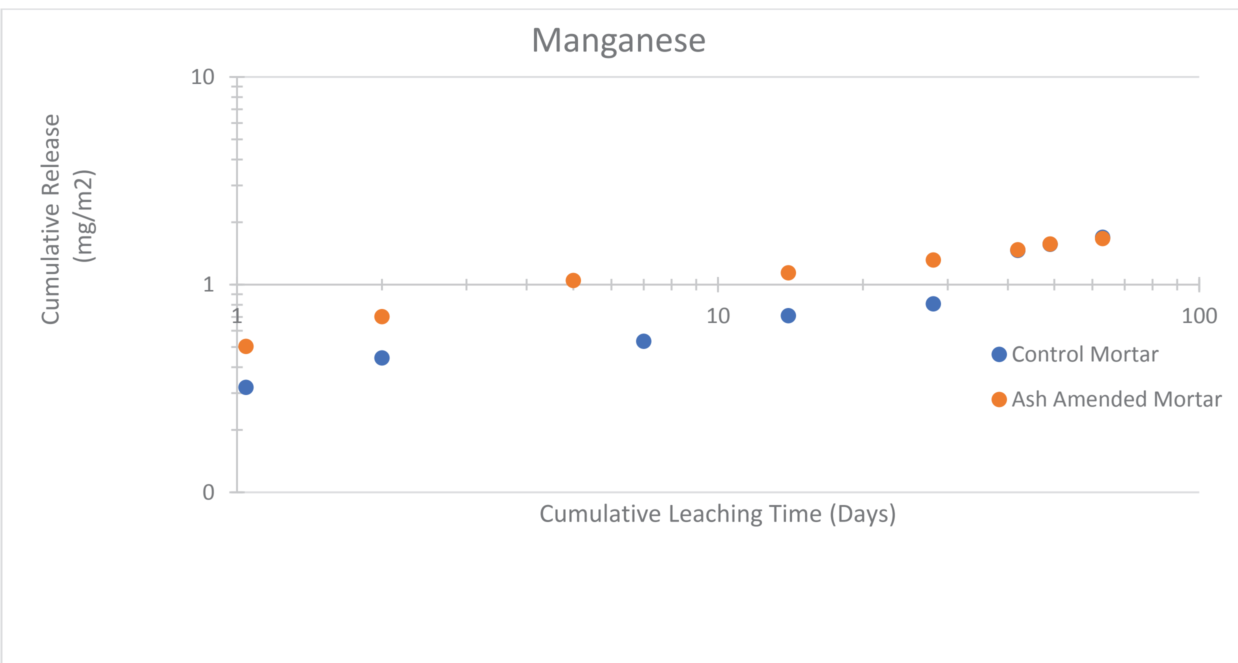


Figure B-8. Cumulative mass release for manganese, EPA Method 1315, for control and ash-amended mortar specimens

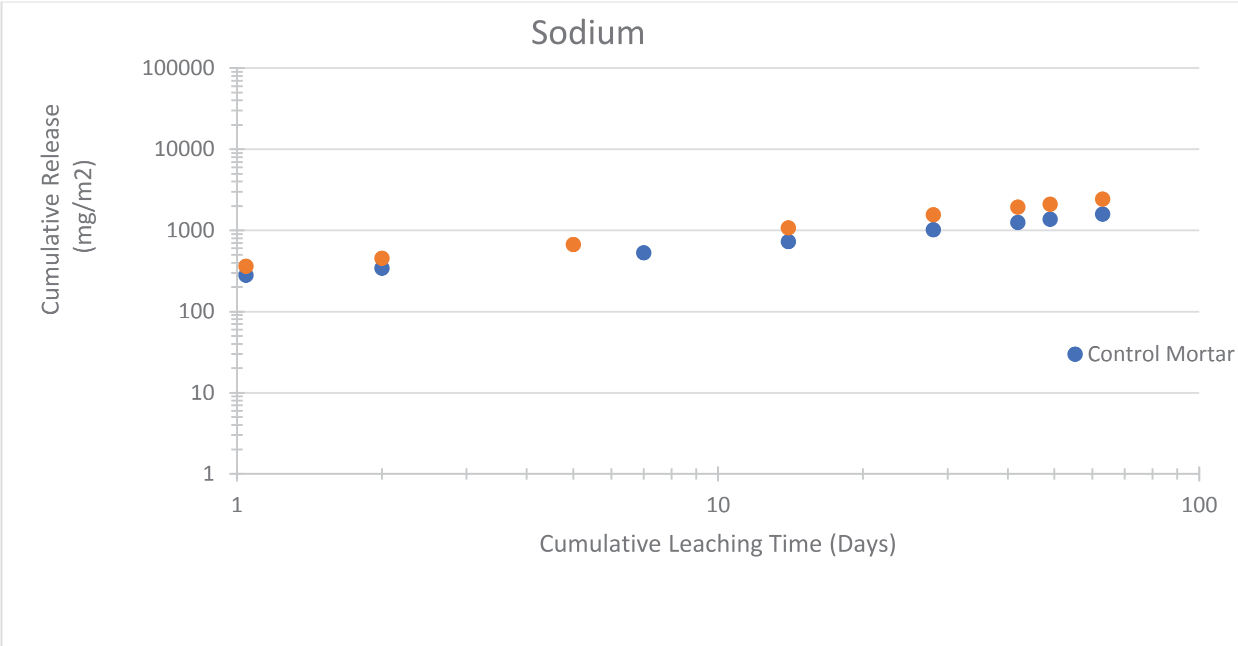


Figure B-9. Cumulative mass release for sodium, EPA Method 1315, for control and ash-amended mortar specimens

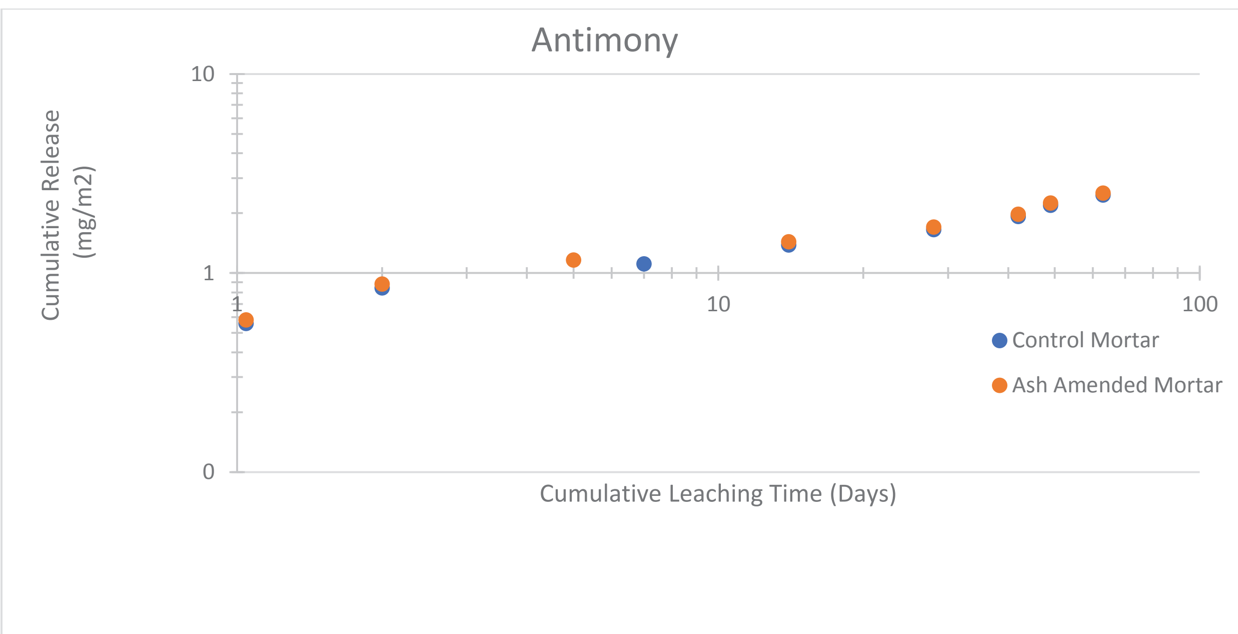


Figure B-10. Cumulative mass release for antimony, EPA Method 1315, for control and ash-amended mortar specimens

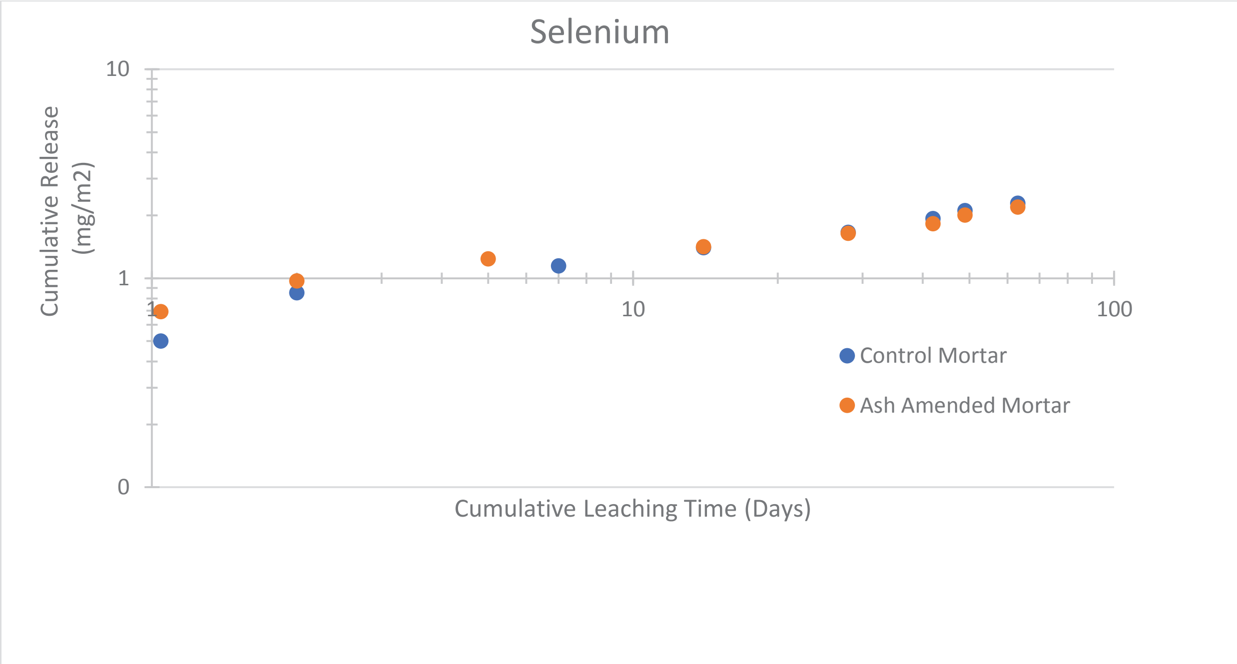


Figure B-11. Cumulative mass release for selenium, EPA Method 1315, for control and ash-amended mortar specimens

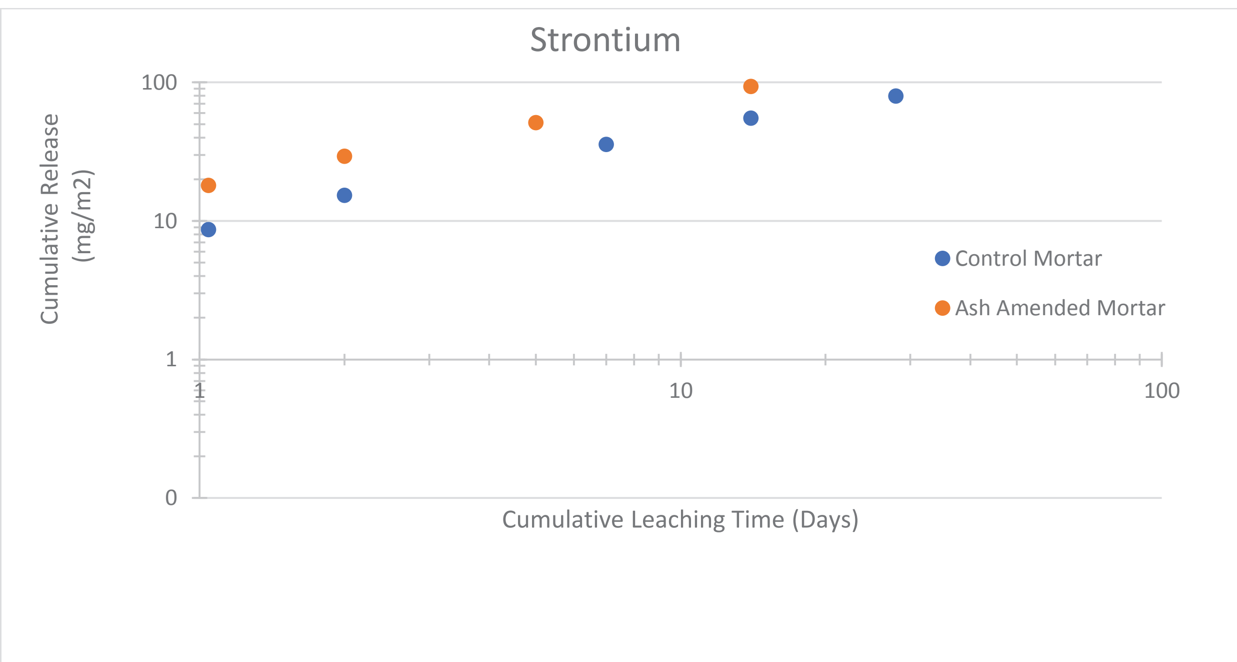


Figure B-12. Cumulative mass release for strontium, EPA Method 1315, for control and ash-amended mortar specimens

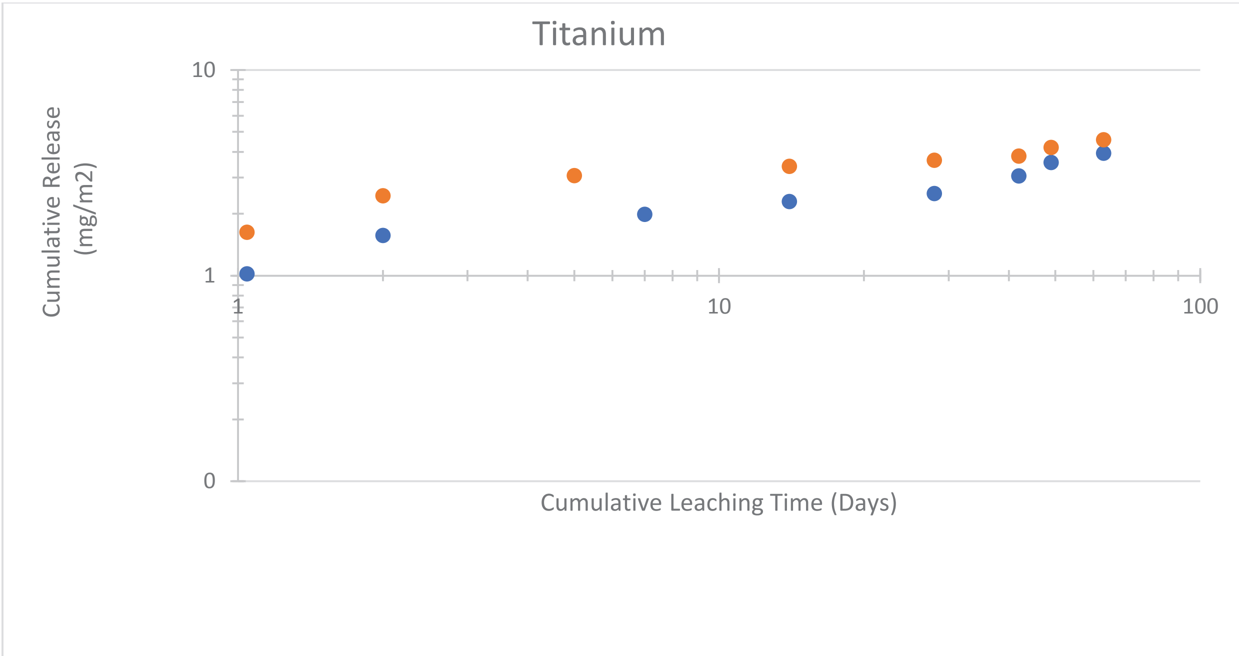


Figure B-13. Cumulative mass release for titanium, EPA Method 1315, for control and ash-amended mortar specimens

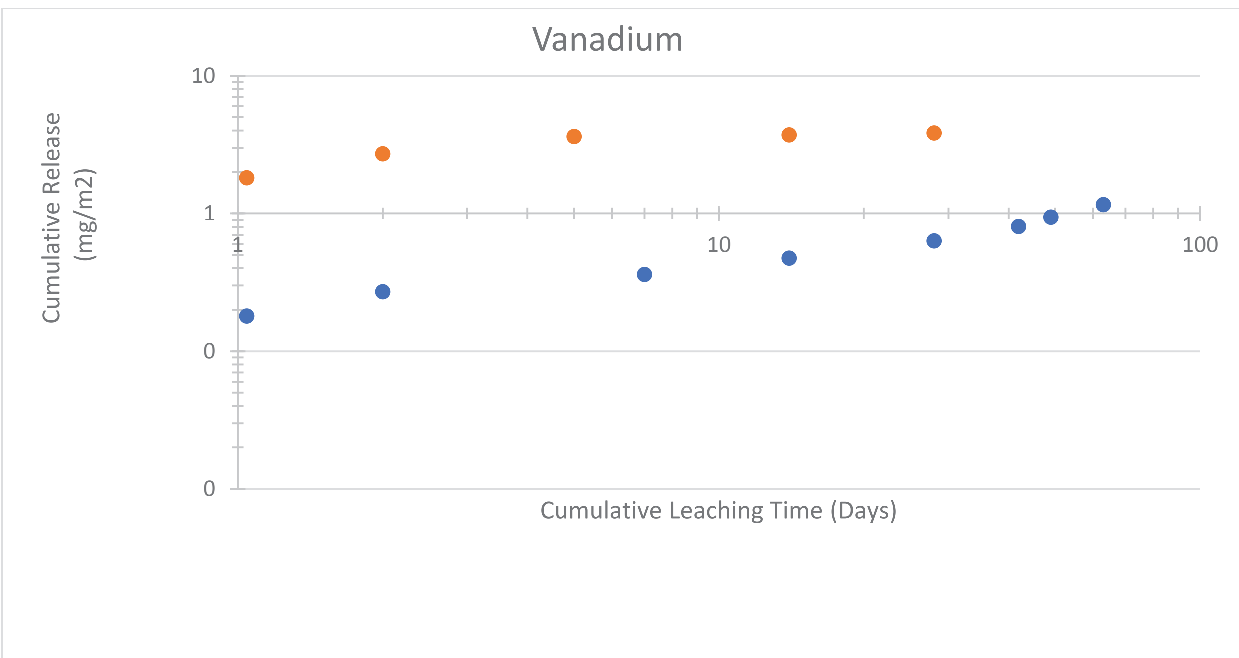


Figure B-14. Cumulative mass release for vanadium, EPA Method 1315, for control and ash-amended mortar specimens

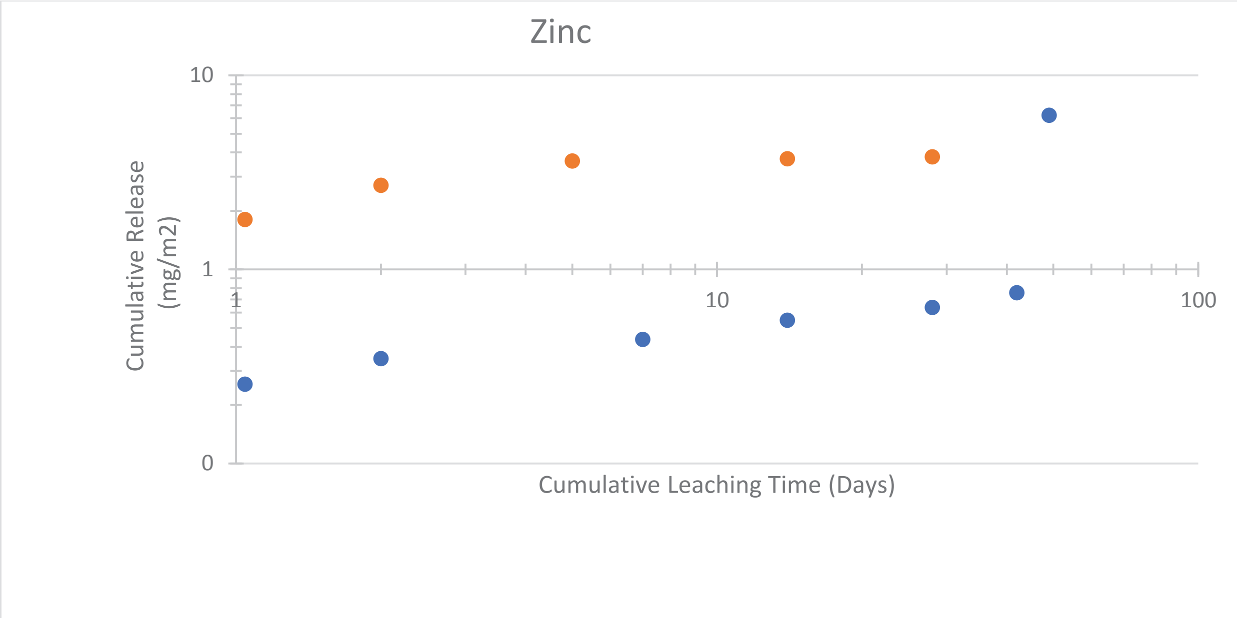


Figure B-15. Cumulative mass release for zinc, EPA Method 1315, for control and ash-amended mortar specimens

Appendix C: EPA Method 1315 Mass Release, All Concrete Specimens Above Detection Limit

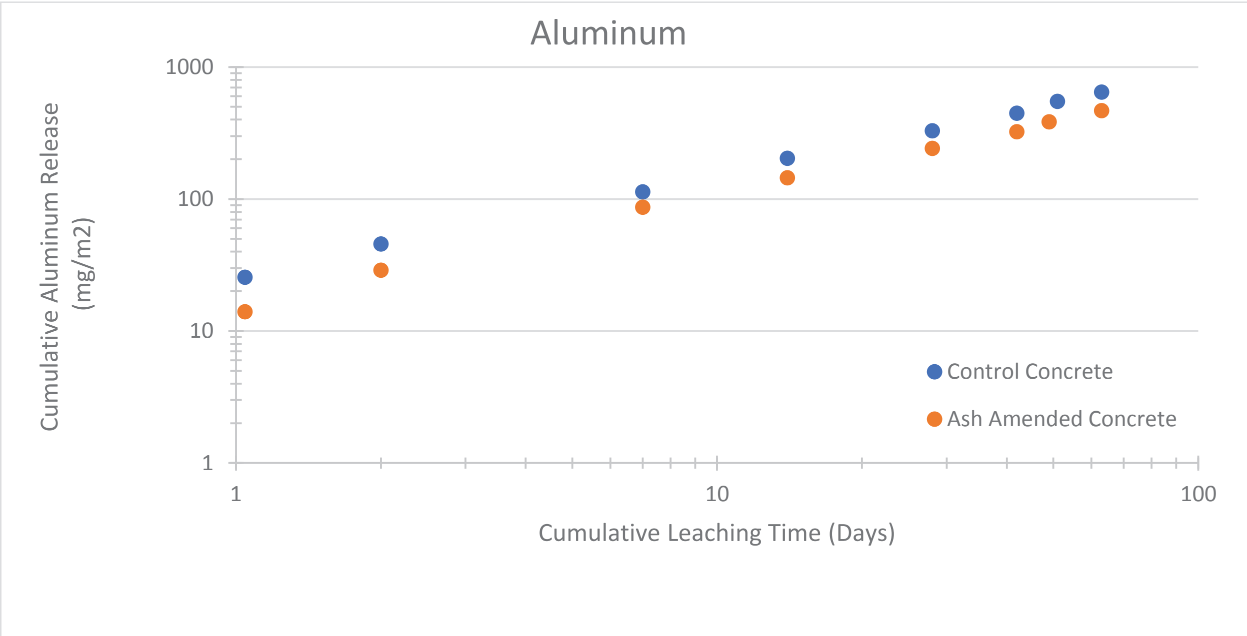


Figure C-1. Cumulative mass release for aluminum, EPA Method 1315, for control and ash-amended concrete specimens

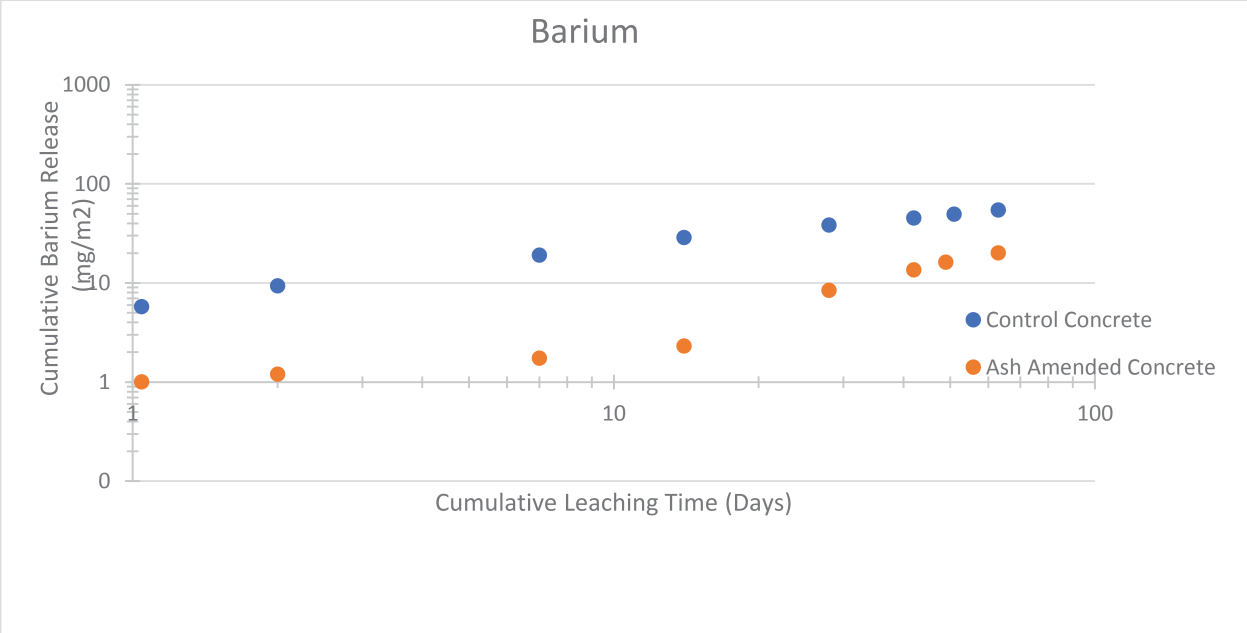


Figure C-2. Cumulative mass release for barium, EPA Method 1315, for control and ash-amended concrete specimens

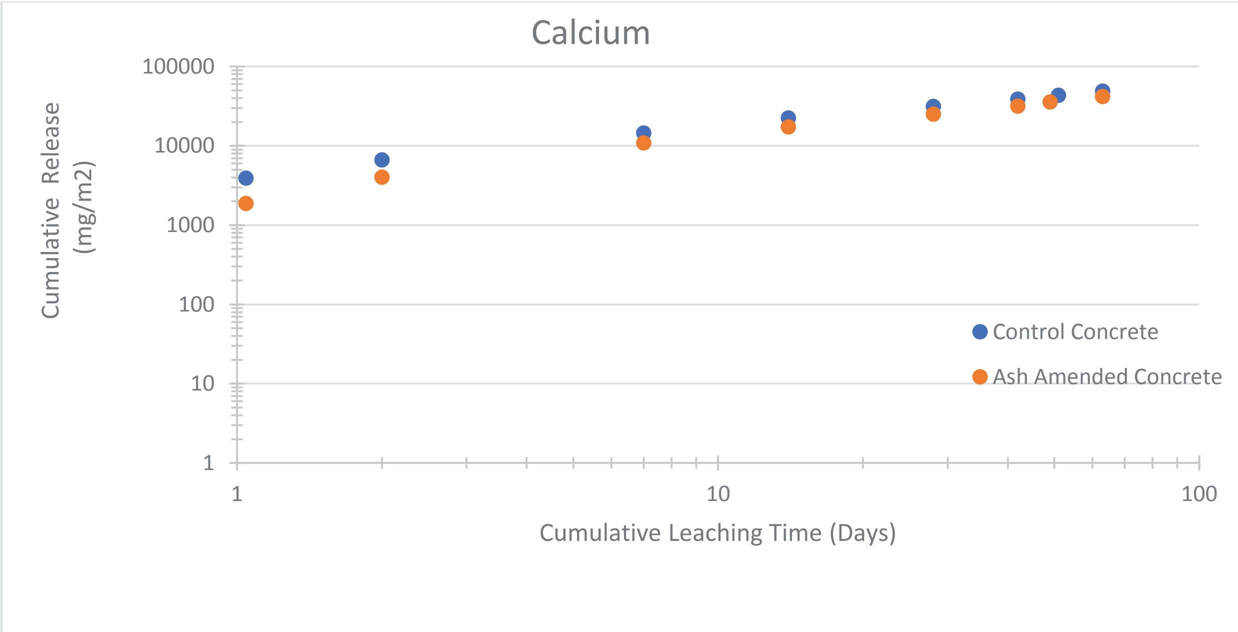


Figure C-3. Cumulative mass release for calcium, EPA Method 1315, for control and ash-amended concrete specimens

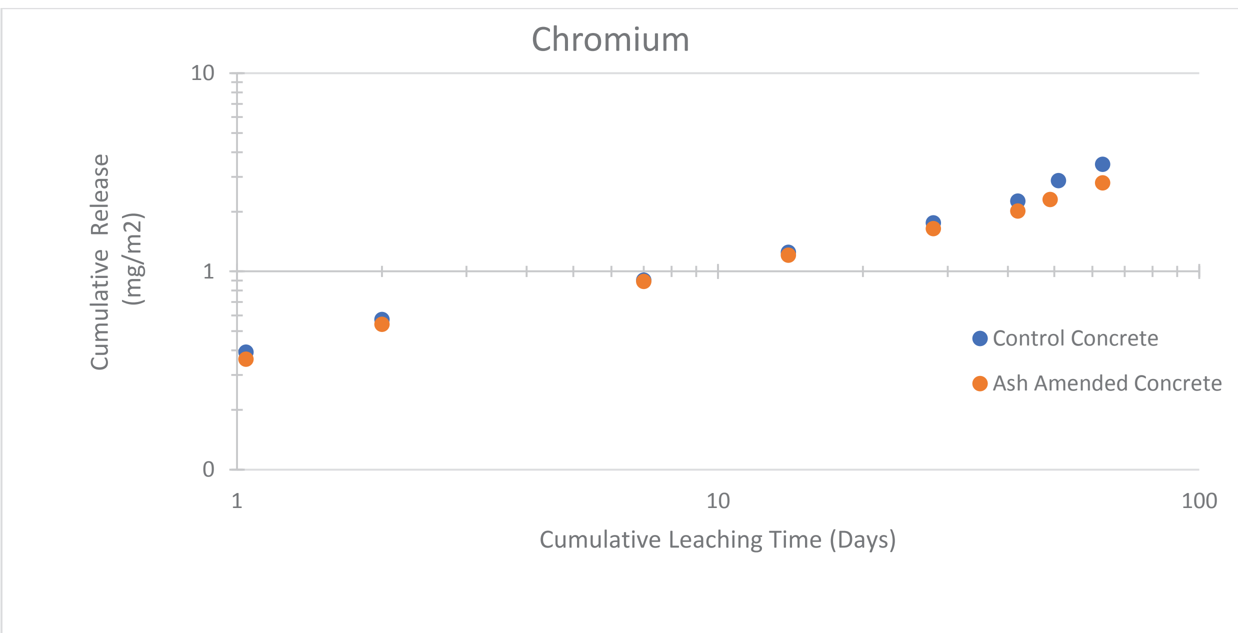


Figure C-4. Cumulative mass release for chromium, EPA Method 1315, for control and ash-amended concrete specimens

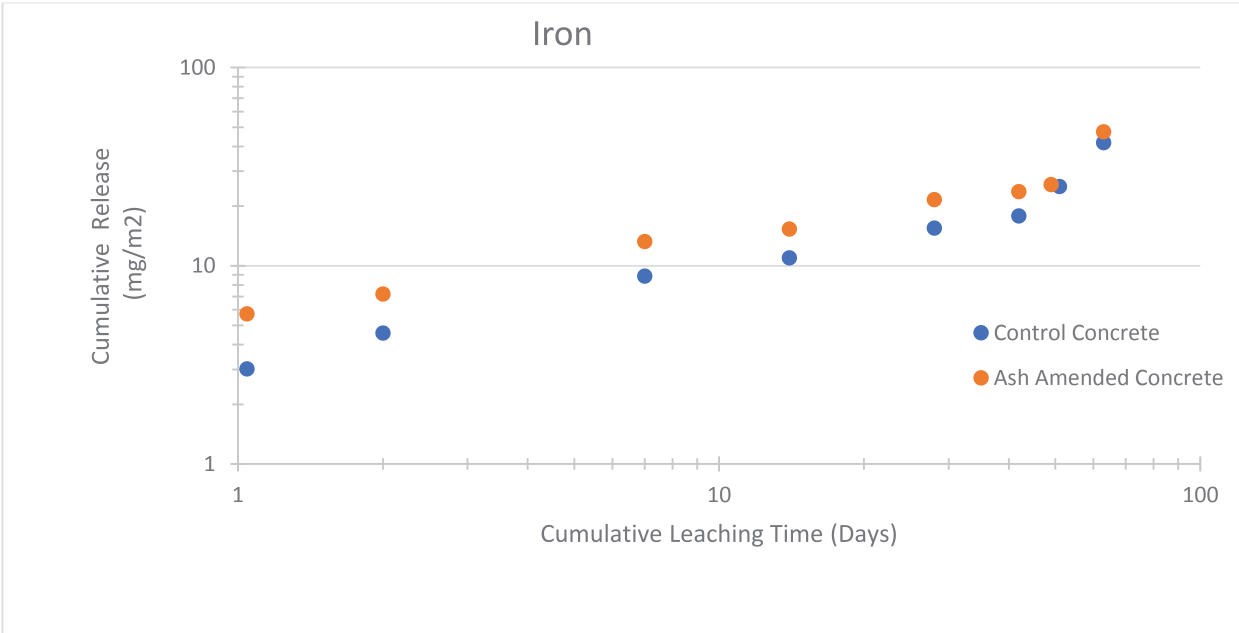


Figure C-5: Cumulative mass release for iron, EPA Method 1315, for control and ash-amended concrete specimens

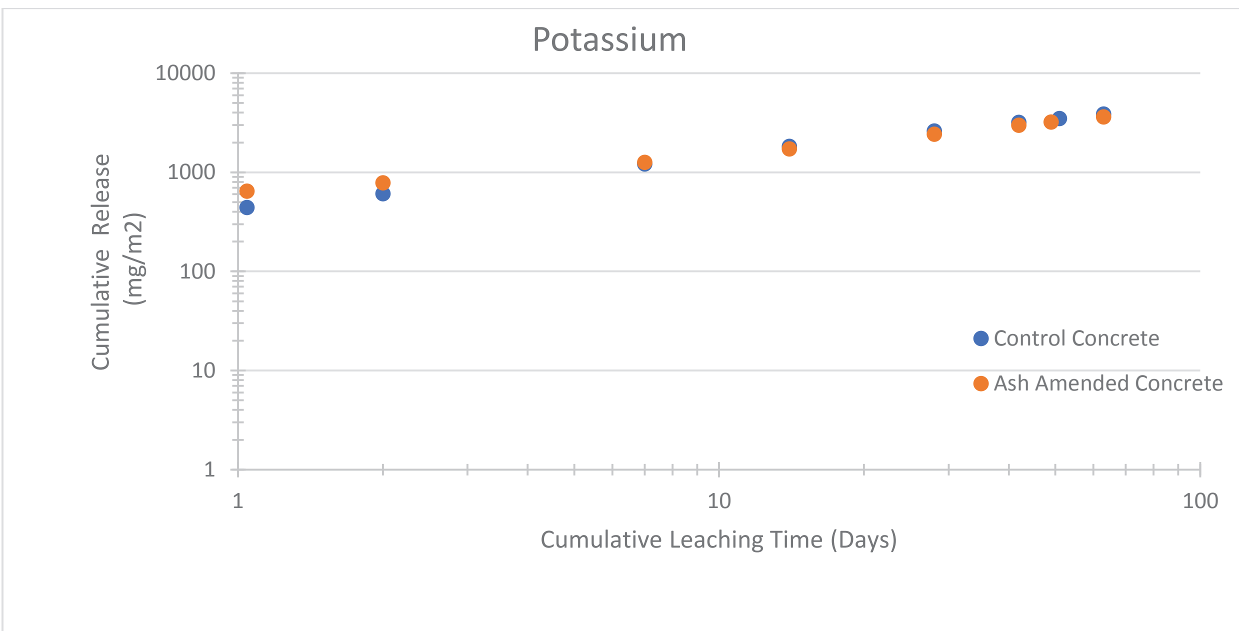


Figure C-6 Cumulative mass release for potassium, EPA Method 1315, for control and ash-amended concrete specimens

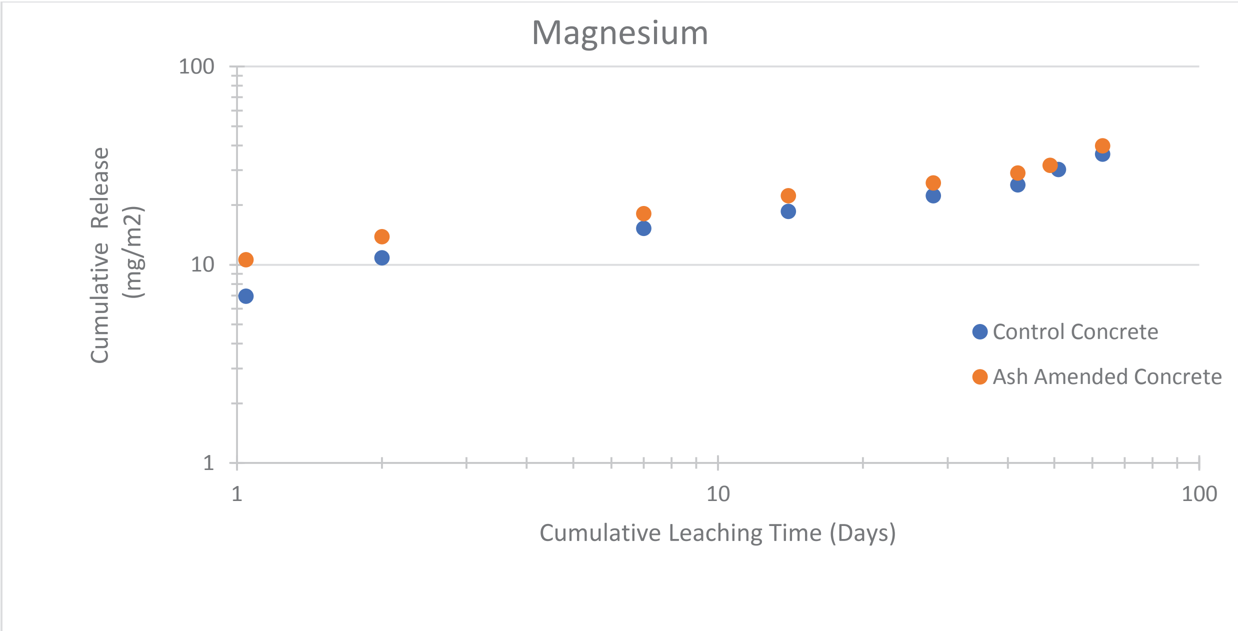


Figure C-7. Cumulative mass release for magnesium, EPA Method 1315, for control and ash-amended concrete specimens

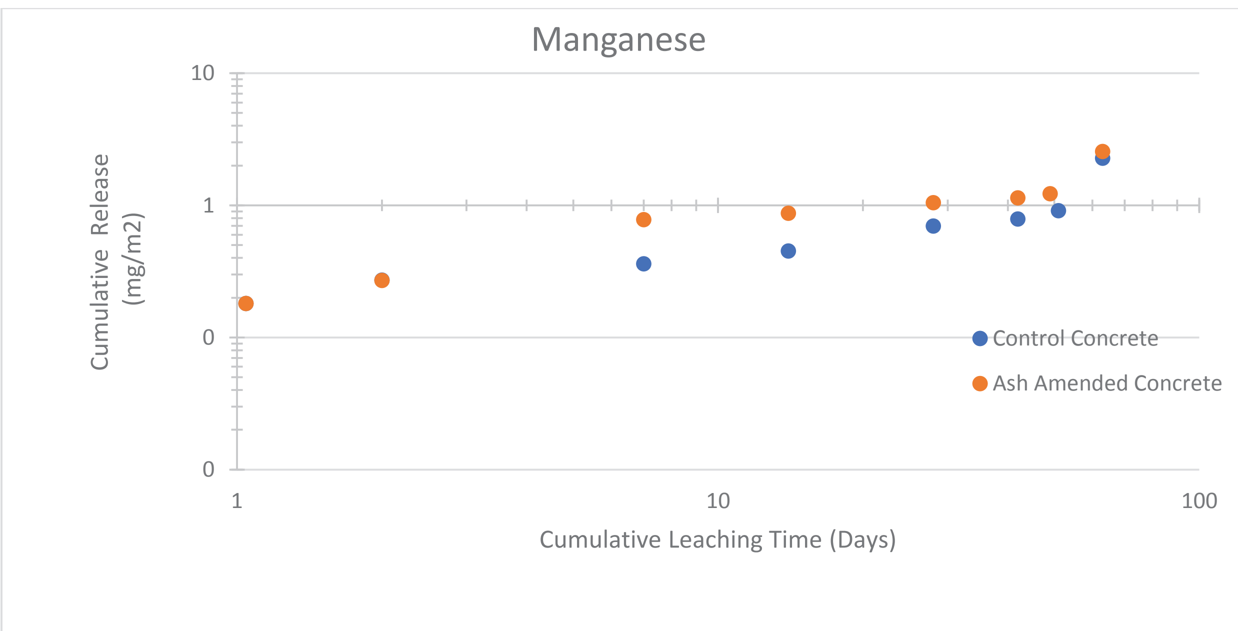


Figure C-8. Cumulative mass release for manganese, EPA Method 1315, for control and ash-amended concrete specimens

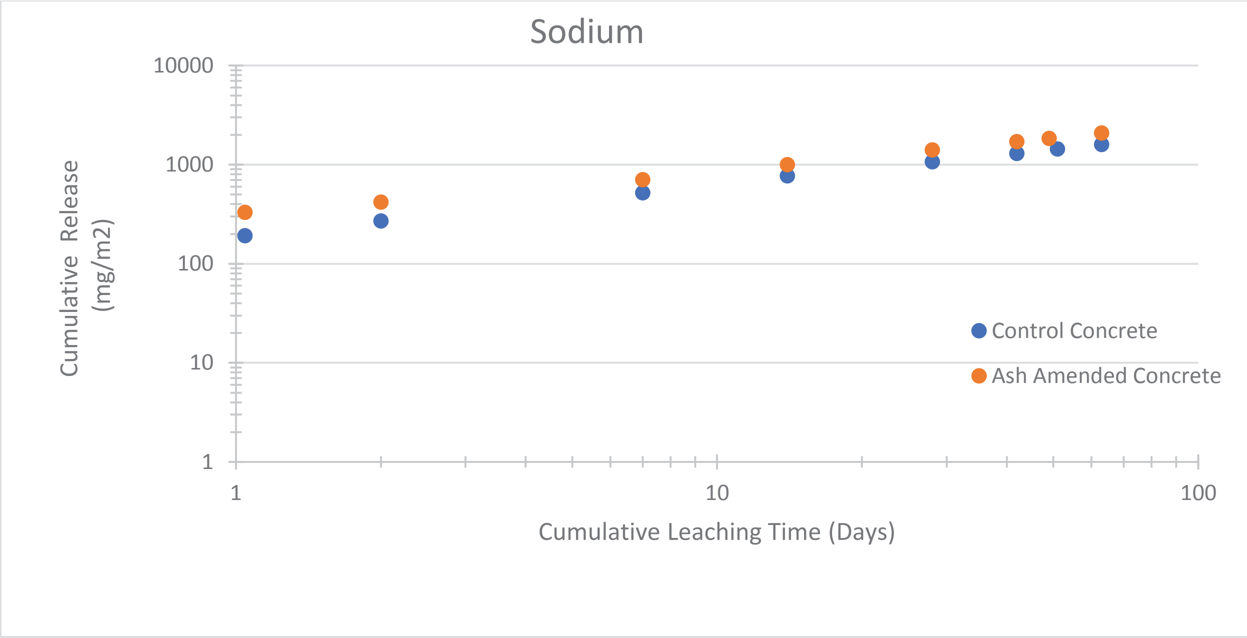


Figure C-9. Cumulative mass release for sodium, EPA Method 1315, for control and ash-amended concrete specimens

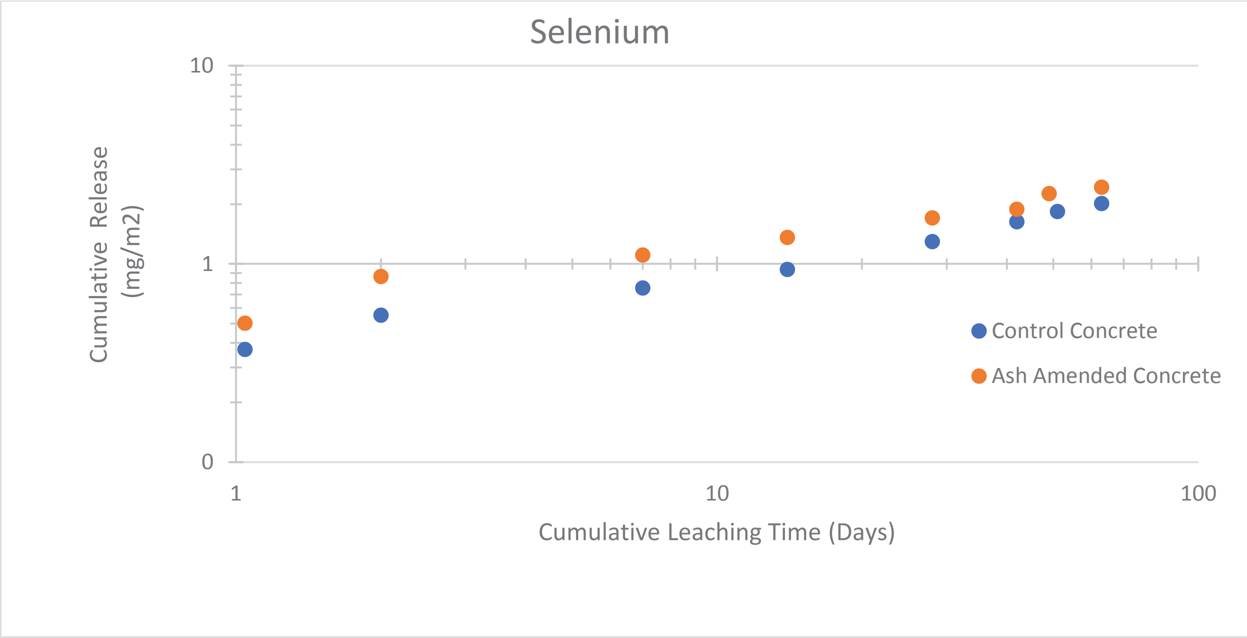


Figure C-10. Cumulative mass release for selenium, EPA Method 1315, for control and ash-amended concrete specimens

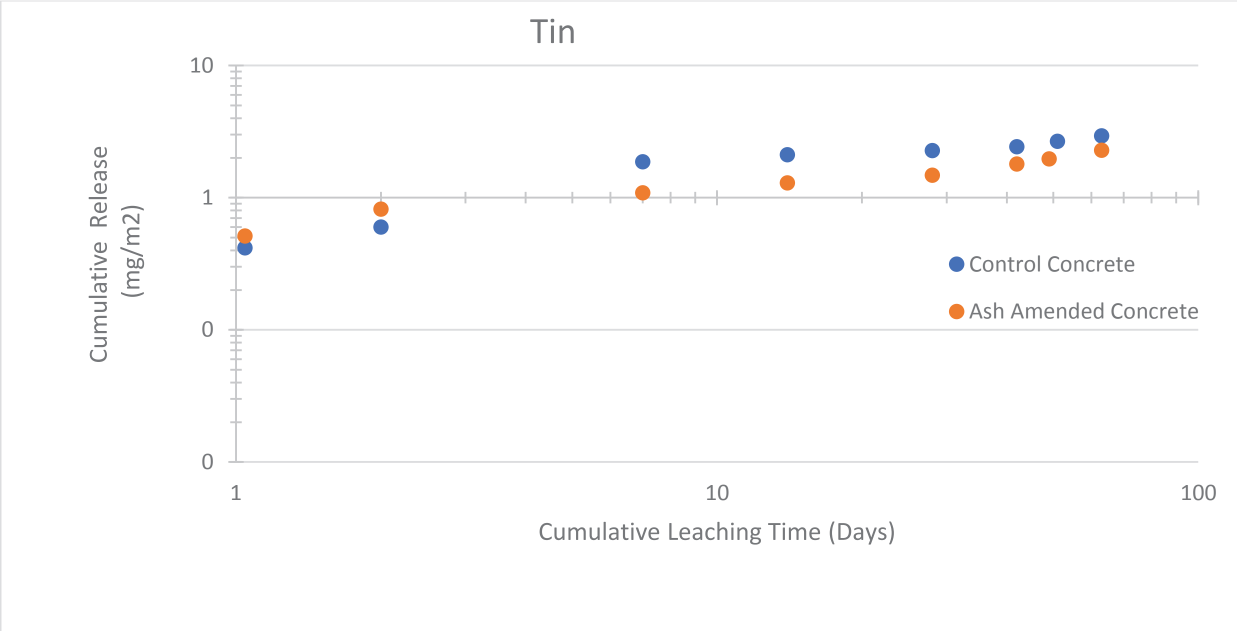


Figure C-11. Cumulative mass release for tin, EPA Method 1315, for control and ash-amended concrete specimens

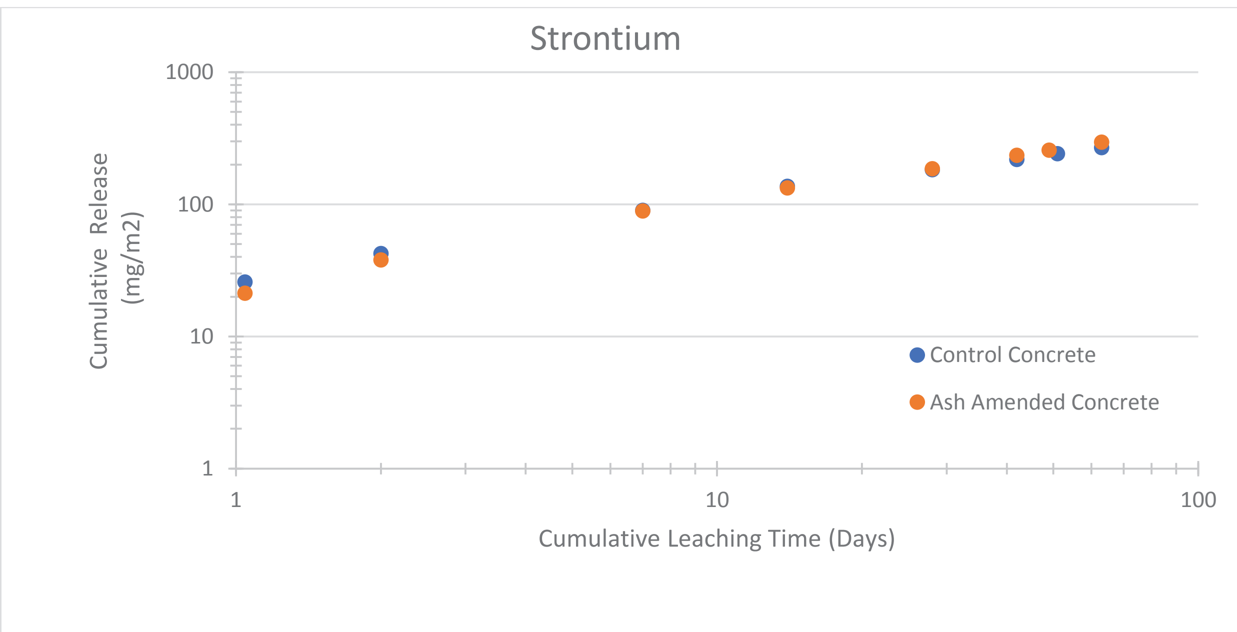


Figure C-12. Cumulative mass release for strontium, EPA Method 1315, for control and ash-amended concrete specimens

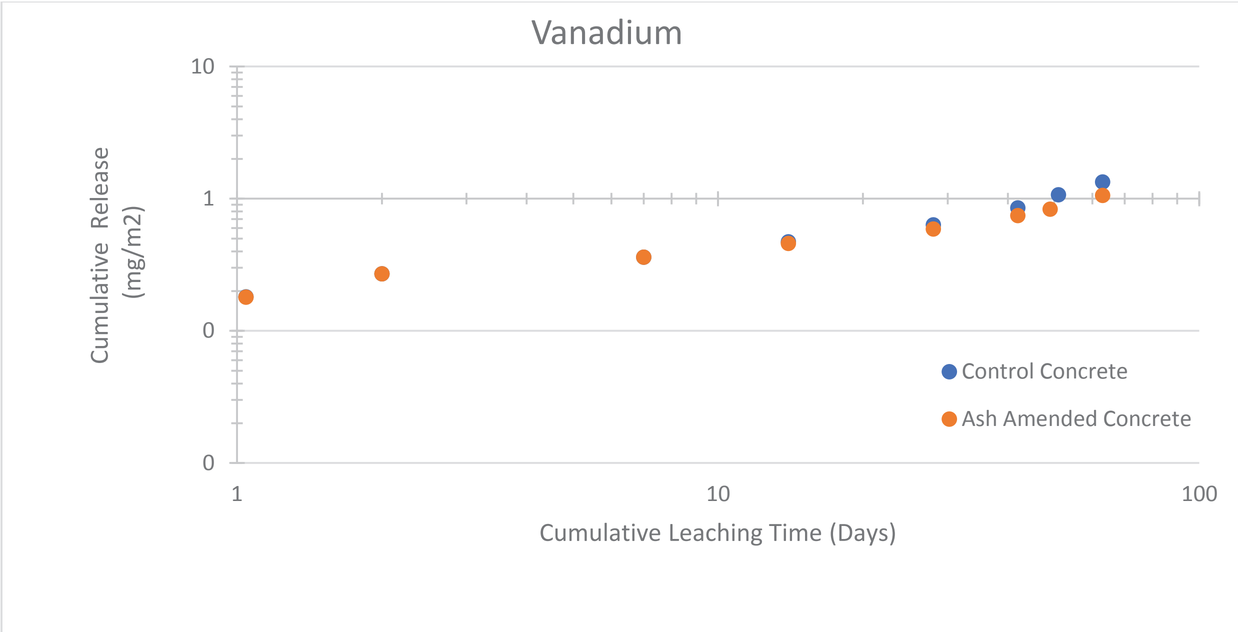


Figure C-13. Cumulative mass release for vanadium, EPA Method 1315, for control and ash-amended concrete specimens

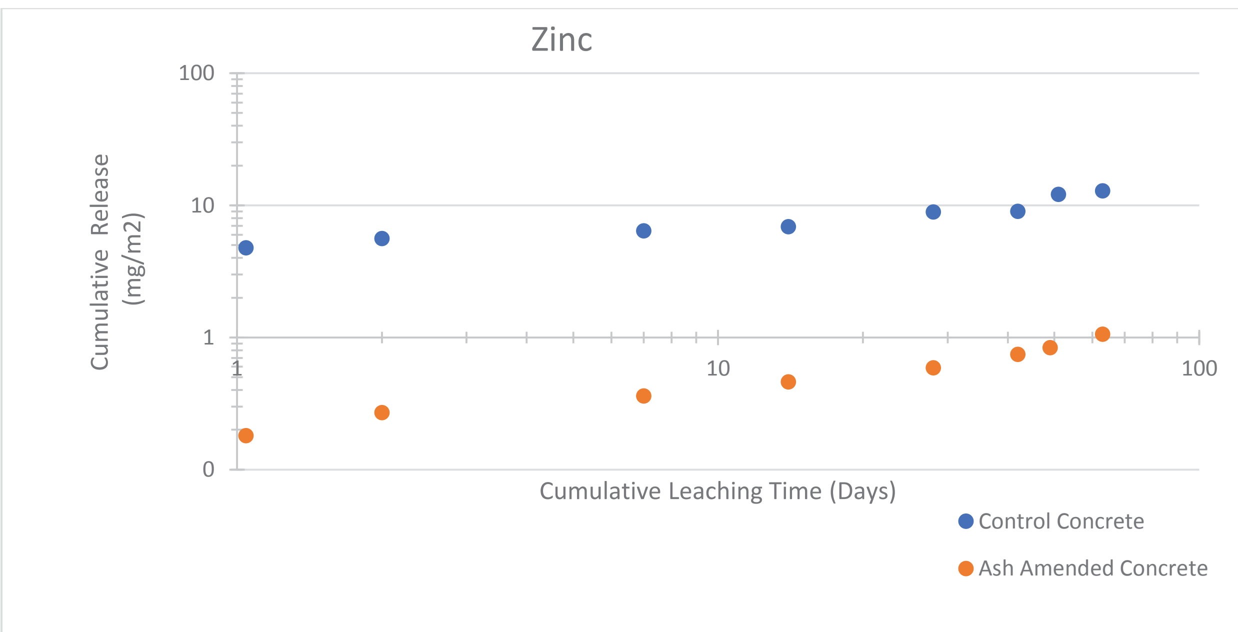


Figure C-14. Cumulative mass release for zinc, EPA Method 1315, for control and ash-amended concrete specimens

Appendix D: Method 1313 Data, All Specimens

Table C-1. 1313 results for control mortar specimens

Control cement mortar 1313	*pH control point*					
Leached concentration (mg/L)	**12**	**10**	**9**	**7**	**6**	**5**
Aluminum	0.820	1.17	0.464	2.55	3.31	3.29
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Boron	0.003	0.233	0.260	0.597	0.67	0.936
Barium	1.885	0.620	0.586	0.585	1.13	1.38
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Calcium	1550	6110	6530	8870	7380	8790
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	0.00575	0.00800
Cobalt	0.00800	< 0.006	< 0.006	0.00780	0.123	0.125
Chromium	0.0830	1.25	1.38	2.02	0.735	1.83
Copper	< 0.002	< 0.002	< 0.002	< 0.002	0.0648	0.0700
Iron	0.549	0.792	0.324	1.96	2.10	2.11
Potassium	42.7	42.3	42.8	42.9	49.0	50.3
Magnesium	0.817	32.8	57.7	85.3	87.0	119
Manganese	0.0126	0.0150	0.00510	0.316	3.95	9.21
Molybdenum	0.0690	0.217	0.216	0.486	0.216	0.0290
Sodium	17.3	23.3	24.2	26.1	24.4	38.2
Nickel	< 0.001	< 0.001	< 0.001	0.0256	0.348	0.406
Lead	0.0110	< 0.004	< 0.004	0.0124	0.0278	0.0300
Antimony	0.00300	0.0156	0.0195	0.0224	0.00625	0.0170
Selenium	0.00367	0.0342	0.0372	0.0374	0.0360	0.0380
Tin	0.00227	0.0171	0.0486	0.00480	0.00575	0.00750
Strontium	7.74	12.0	12.4	17.0	13.8	22.0
Titanium	0.223	0.0110	0.0100	0.0142	0.0795	0.0590
Vanadium	< 0.00100	0.0561	0.0672	0.0888	0.0385	0.00600
Zinc	0.0326	< 0.001	< 0.001	0.0202	2.54	4.02

Table C-2. 1313 results for bottom ash-amended mortar specimens

Bottom ash-amended cement mortar 1313	*pH control point*				
Leached concentration (mg/L)	**12**	**11**	**10**	**7**	**5**
Aluminum	0.843	1.12	0.857	0.727	1.23
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Boron	< 0.01	0.0249	0.331	0.656	0.779
Barium	1.20	1.70	0.754	0.494	1.31
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Calcium	906	5570	7990	5720	8740
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	0.0140	0.0174	0.00435	0.0392	0.125
Chromium	0.0855	0.790	2.51	2.02	1.28
Copper	< 0.002	0.0105	0.00720	< 0.002	0.723
Iron	0.564	0.4491	0.612	0.446	0.284
Potassium	36.9	52.2	48.7	21.8	58.0
Magnesium	0.861	0.510	34.95	73.4	102
Manganese	0.0134	0.0120	0.0189	2.16	7.42
Molybdenum	0.0553	0.0336	0.0507	0.486	0.00960
Sodium	21.8	36.1	39.4	20.4	38.7
Nickel	< 0.001	< 0.001	< 0.001	0.140	< 0.001
Lead	0.0120	< 0.004	< 0.004	0.0116	< 0.004
Antimony	0.00520	0.00780	0.0314	0.0224	0.0168
Selenium	0.00380	0.0183	0.0355	0.0216	0.0327
Tin	0.00420	0.00750	0.00540	0.00380	0.0081
Strontium	8.54	17.5	19.6	14.1	20.4
Titanium	0.0321	0.0110	0.0100	0.0100	0.0120
Vanadium	< 0.001	0.00300	0.0618	0.0490	0.072
Zinc	0.0292	< 0.001	< 0.001	0.547	7.55

Table C-3. 1313 results for control concrete specimens

Control cement concrete 1313	*pH control point*						
Leached concentration (mg/L)	**12**	**11**	**10**	**9**	**7**	**6**	**5**
Aluminum	0.841	1.47	0.825	0.464	0.731	3.21	7.10
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	0.0118	0.0130
Boron	< 0.01	< 0.01	0.0628	0.260	0.231	0.409	0.523
Barium	0.805	0.874	0.329	0.586	0.742	1.54	2.07
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.001
Calcium	485	2280	2040	6525	5560	10,600	13,800
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	0.0638	0.0890
Chromium	0.0640	0.341	0.536	1.38	0.316	0.269	0.226
Copper	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.115	0.175
Iron	0.619	0.568	0.626	0.324	0.506	1.96	5.28
Potassium	587	21.0	11.6	42.8	9.39	26.6	28.7
Magnesium	0.883	0.843	2.50	57.7	57.3	171	146
Manganese	0.0143	0.0128	0.0133	0.00510	0.814	2.10	3.35
Molybdenum	0.0373	0.208	0.200	0.216	0.0936	0.179	0.202
Sodium	8.27	9.20	5.98	24.2	7.84	17.1	17.6
Nickel	< 0.001	< 0.001	< 0.001	< 0.001	0.0960	0.191	0.251
Lead	0.00487	0.00650	0.00600	< 0.004	0.00920	0.0263	0.0365
Antimony	0.00593	0.00610	0.00950	0.0195	0.00540	0.00900	0.00300
Selenium	0.00840	0.0113	0.0145	0.0372	0.0180	0.0338	0.0320
Tin	0.0360	0.00350	0.00220	0.0486	0.004	0.008	0.0105
Strontium	3.50	6.57	5.00	12.4	11.1	22.7	29.4
Titanium	0.0360	.0138	0.0188	0.0100	0.00300	0.0435	0.164
Vanadium	< 0.001	< 0.001	0.00940	0.0672	0.0454	0.121	0.116
Zinc	0.00513	0.00200	0.00220	< 0.001	0.350	1.12	2.13

Table C-4. 1313 results for bottom ash-amended concrete specimens

Bottom ash-amended cement concrete 1313	*pH control point*						
Leached concentration (mg/L)	**12**	**11**	**10**	**9**	**7**	**6**	**5**
Aluminum	0.822	0.926	0.436	0.618	0.724	3.68	4.24
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Boron	0.0175	0.006	0.167	0.210	0.354	0.471	0.523
Barium	0.865	0.682	0.382	0.690	0.658	1.17	1.47
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Calcium	1,136	2,175	3279	5505	4,210	10,480	15,322
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	0.0116	0.00980	0.00420	0.00510	0.0294	0.0350	0.0688
Chromium	0.149	0.404	1.29	1.75	0.684	0.982	0.243
Copper	< 0.002	< 0.002	0.00240	0.0480	0.0708	0.0753	0.327
Iron	0.558	0.499	0.325	0.484	0.433	2.41	2.46
Potassium	448	21.6	23.8	35.2	11.3	27.9	26.2
Magnesium	0.793	0.837	16.1	54.4	92.3	200	222
Manganese	0.0138	0.0120	0.00600	0.0132	2.71	2.20	6.98
Molybdenum	0.0107	0.0266	0.0492	0.0582	0.0138	0.0335	0.0220
Sodium	15.7	13.9	18.2	28.9	10.1	22.2	22.5
Nickel	< 0.001	< 0.001	< 0.001	< 0.001	0.0998	0.164	0.227
Lead	0.00708	0.00900	< 0.004	< 0.004	0.00740	0.0265	0.0360
Antimony	0.00680	0.00680	0.0231	0.0288	0.0116	0.0118	< 0.003
Selenium	0.00744	0.00790	0.0282	0.0261	0.00140	0.0293	0.0318
Tin	0.00572	0.00340	0.00480	0.00540	0.00340	0.00675	0.0123
Strontium	7.12	8.56	9.79	15.2	10.1	24.2	36.2
Titanium	0.0280	0.0143	0.0300	0.005	0.0115	0.0638	0.0153
Vanadium	< 0.001	< 0.001	0.0318	0.0636	0.0644	0.161	0.210
Zinc	0.00808	< 0.001	< 0.001	< 0.001	2.09	0.644	3.22

Department of Solid Waste Management
2525 NW 62nd Street • Suite 5100
Miami, Florida 33147
T 305-514-6666

MIAMI-DADE COUNTY

miamidade.gov

January 19, 2022

Mr. William Meredith
Area Asset Manager
Covanta Dade Renewable Energy LTD
6990 NW 97th Avenue
Doral, FL 33178

RE: Extension - Ash Processing / Mobile Metals Test Project

Dear Mr. Meredith:

Pursuant to the Ash Processing / Mobile Metals Test Project letter dated January 25, 2021, (see attachment) the County hereby grants Covanta a 12-month extension (Extension) on the previously issued letter. The Extension is subject to all terms and conditions included in the original letter. This Extension shall not exceed one (1) year in duration.

If you agree with the terms of this Extension, kindly sign in the space indicated below and return an executed copy of this letter to me within 15 business days at the above address. If you have any questions or concerns regarding this letter, please contact me.

Sincerely,

Michael J. Fernandez
Director

Date: ____________________

AGREED AND ACCEPTED
Covanta Dade Renewable Energy Ltd.

William Meredith
Business Manager

Date: 2/24/22

Attachment

c: David Stephen Hope, Assistant County Attorney
Achaya Kelapanda, Assistant Director, Technical Services
Johanna Faddis, Sr. Executive Assistant to the Director

FLORIDA DEPARTMENT OF
Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Ron DeSantis
Governor

Jeanette Nuñez
Lt. Governor

Noah Valenstein
Secretary

July 15, 2020

E-mail:
Achaya.Kelapanda@miamidade.gov

Achaya Kelepanda, P.E., Assistant Director
Miami-Dade County Solid Waste Management
2525 NW 62 Street, Suite 5100
Miami, FL 33147

RE: Beneficial Use Request to Conduct A Pilot Project for the Processing of WTE Bottom Ash and Use as a Kiln Feed Ingredient for Cement Production
Miami-Dade Resource Recovery Facility
Facility ID No. 56825, COC PA 77-08

Dear Mr. Kelepanda:

In response to the request from the Miami-Dade County dated April 24, 2020 and the Response to a Request for Additional Information dated June 1, 2020, concerning conducting a pilot project to operate a Mobile Metals Recovery System (MMR) at the Miami-Dade Resource Recovery Facility (MDRRF) site monofill for a period of up to 12 months to evaluate additional removal of ferrous and non-ferrous metals from the bottom ash and a larger scale test for potential re-use of the small aggregate fraction from the processed bottom ash as a kiln feed ingredient in cement production. The following items were indicated in your request:

a. In 2018, Titan Cement in coordination with Miami-Dade County completed a short-term test using approximately 1,000 tons of bottom ash as a kiln feed ingredient in cement production. The summary report indicated no increased direct exposure or leaching risk associated with WTE bottom ash incorporated into cement production with a kiln feed replacement value of 2.8%. The test showed additional processing of the bottom ash was required for acceptable usage on a longer-term basis.

b. Up to 90,000 tons of WTE bottom ash from the Miami-Dade Resource Recovery Facility will be stockpiled and processed at the existing ash monofill at the Miami-Dade Resource Recovery Facility, during the pilot project.

c. The Miami-Dade Resource Recovery Facility is operated by Covanta Energy for Miami-Dade County Department of Solid Waste Management.

d. The Mobile Metal Recovery System will be located and operated within Cell 20 of the ash monofill in accordance with the facility's Operation Plan including the Mobile Metal Recovery System Operations. The project will utilize the monofill's existing stormwater controls and leachate collection systems.

e. Ash will be transported from the WTE facility and stockpiled within Cell 20 as shown on the site plan (Figure 1 – Attached) for one to two weeks prior to processing. The throughput rate of the Mobile Metal Recovery System is approximately 50 tons/hour and varies with ash moisture content. Processing will result in the following: a ferrous metal stockpile, a non-ferrous metal stockpile, a small aggregate stockpile, and the remaining post-processed ash stockpile.

f. Post-processing, the stockpiled materials will be stored in the locations shown on Figure 1. The metals, both ferrous and non-ferrous are stored in concrete block bunkers as described in the request, until enough is recovered for a full truckload for shipment.

g. Recovered materials from the processing will be handled as follows:

Ferrous Metals	Shipped to local buyer for sale
Non-Ferrous Metal	Shipped to Covanta Metals Management, Fairless Hills, PA for processing and sale
Small Aggregate	Shipped to Titan Cement, or other permitted cement facility for use in cement and flowable fill concrete
Post-processed Ash	Directed to on-site ash monofill operating face for disposal

h. The post-processed small aggregate from the WTE bottom ash will be transported to the Titan Pennusco Cement Facility located at 10100 NW 121st Way, 235, Medley, Miami-Dade County, Florida. At the Titan Pennusco site, it will be stored in a covered storage area before being incorporated as a raw ingredient in cement production.

i. The pilot test will involve the processing of the bottom ash to remove metals and incorporate small aggregate from the WTE bottom ash as a kiln feed ingredient in cement and flowable fill concrete, with a maximum replacement of approximately 3% of the total kiln feed. The pilot test period will not exceed 12 months.

j. Care will be taken to minimize the amount of time between the delivery of the WTE ash to Titan Pennusco Cement Facility and its incorporation into cement production.

k. The WTE bottom ash amended clinker and cement products created during this trial will be extensively evaluated and tested for their physical and environmental performance compared to standard cement products.

Section 403.7045(5), Florida Statutes (F.S.) specifies the following:

> Ash residue generated by a solid waste management facility from the burning of solid waste must be disposed of in a properly designed solid waste disposal area that complies with standards developed by the department for the disposal of such ash residue. The department shall work with solid waste management facilities that burn solid waste to identify and develop methods for recycling and reuse of ash residue or treated ash residue, and the department may allow such recycling or reuse by an applicant who demonstrates that no significant threat to public health will result and that applicable department standards and criteria will not be violated.

Based on review of the information submitted, the Department has determined that the proposed beneficial use request concerning conducting a pilot test of processing up to 90,000 tons of WTE bottom ash to meets the criteria specified in Section 403.7045(5), F.S.

As a result, the Department has no objections to the beneficial use request submitted on April 24, 2020 and supplemented with the Response to the Request for Additional Information received June 2, 2020, concerning conducting a pilot test of processing up to 90,000 tons of WTE bottom ash to explore the use of the post-processed small aggregate fraction from the bottom ash as a kiln feed component in cement production.

Criteria for future Beneficial Use Determination following this Pilot Project:

1. Following batching of the concrete products, unused ash-derived aggregates will be returned to the Miami-Dade Resource Recovery Facility for proper management.
2. Upon reasonable notice to the County, Department staff or agents with proper identification shall have permission to enter, inspect, sample and test as needed to verify compliance with the requirements of Chapter 403, F.S.
3. Miami-Dade County shall submit a progress/summary report summarizing all activities completed and sampling/monitoring results (as applicable). Miami-Dade must submit the summary report within 60 days from the end of the pilot project. The report shall contain the results of the evaluation and testing of the WTE bottom ash amended clinker and cement products, amounts of bottom ash processed, amounts of post-processed materials and how they are disposed, sold, or otherwise handled.

Please be aware that neither this letter nor the statutory exemption releases any person from liability for causing pollution or violating any other state or federal regulations or local ordinances. If you have any questions, please contact El Kromhout at (850) 245-8744.

Sincerely,

____

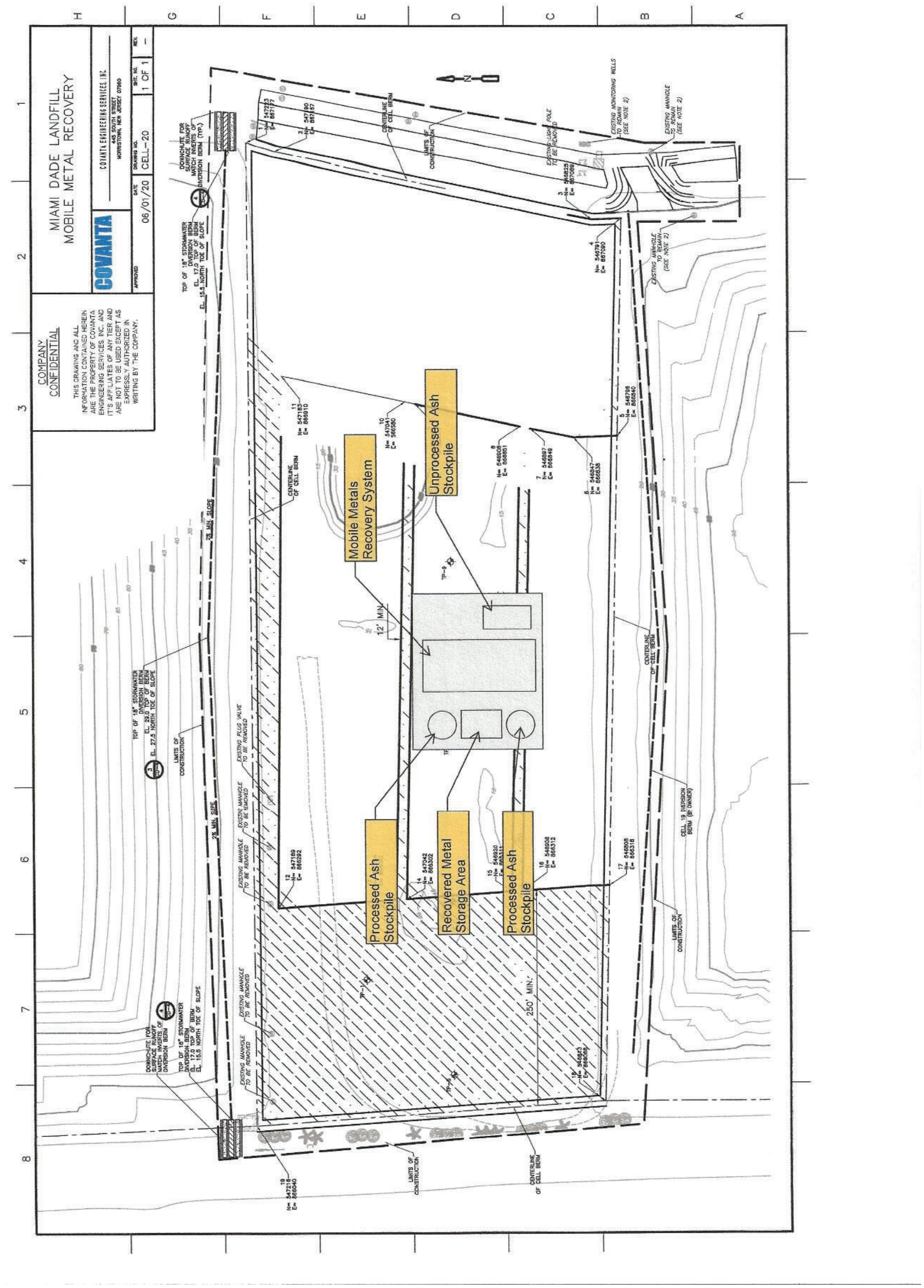
Tim Bahr, P.G.
Director, Division of Waste Management

Referenced Documents

1. Beneficial Use Request to Conduct A Pilot Project for the Processing of WTE Bottom Ash and Use as a Kiln Feed Ingredient for Cement Production, received by the Department April 24, 2020.
   https://depedms.dep.state.fl.us:443/Oculus/servlet/shell?command=getEntity&[guid=8.312378.1]&[profile=Permitting_Authorization
2. Response to a Request for Additional Information dated June 1, 2020 and received by the Department June 2, 2020.
   https://depedms.dep.state.fl.us:443/Oculus/servlet/shell?command=getEntity&[guid=8.315035.1]&[profile=Permitting_Authorization

Copies furnished to:
Ann Seiler, Siting Coordination, Ann.Seiler@FloridaDEP.gov
Cindy Mulkey, Siting Corrdination, Cindy.Mulkey@FloridaDEP.gov
Kim Walker, DWM PCAP, Kim.Walker@FloridaDEP.gov
El Kromhout, P.G., DWM PCAP Solid Waste, Elizabeth.Kromhout@FloridaDEP.gov
Stephanie Allois, Covanta Energy, SAllois@covanta.com

Figure 1


MIAMI DADE LANDFILL
MOBILE METAL RECOVERY
COVANTA
06/01/20
CELL-20
1 OF 1
COMPANY CONFIDENTIAL
Mobile Metals Recovery System
Unprocessed Ash Stockpile
Processed Ash Stockpile
Recovered Metal Storage Area
Processed Ash Stockpile
12' MIN.
250' MIN.

Department of Solid Waste Management
2525 NW 62nd Street • Suite 5100
Miami, Florida 33147
T 305-514-6666

MIAMI-DADE COUNTY

miamidade.gov

January 25, 2021

Mr. William Meredith
Area Asset Manager
Covanta Dade Renewable Energy LTD
6990 NW 97th Avenue
Doral, FL 33178

RE: Ash Processing / Mobile Metals Test Project

Dear Mr. Meredith:

Reference is made to the Fourth Amended and Restated Operations and Management Agreement dated as of October 1, 2009 (the "Agreement"), between Miami-Dade County, Florida (the "County") and Covanta Dade Renewable Energy, Ltd. (the "Company" or "Covanta")). Capitalized terms used in this letter shall have the meanings assigned to such terms in the Agreement.

Pursuant to Section 7.1.5 (Other Payments to Company), "[t]he County may request that the Company provide, on an as-needed basis, miscellaneous services in connection with the Processing or disposal of Solid Waste Accepted by the Company. These miscellaneous services may include studies, environmental test programs or contracts with third parties approved by the County for disposal, recovery or reuse of components of the Solid Waste..."

Whereas on March 8, 2016, the Board of County Commissioners approved Resolution No. R-213-16, which authorized a research service agreement with the University of Florida. The study determined that the ash from the County's Resources Recovery Facility ("RRF") located at 6990 NW 97th Avenue, Doral, Florida was a suitable substitute for coal ash in the production of cement. However, Titan Florida LLC ("Titan") has advised that in order to move forward with the testing of the County's Ash, a cleaner product would be necessary.

Therefore, the County requests that the Company test the removal of metals from the Ash in order to further evaluate the feasibility of reusing the Ash for beneficial purposes. The test shall not take longer than twelve (12) months. The County agrees to make a portion of the ash landfill at the RRF Site (*see* Attachment 1), available to Covanta for operation of a mobile metals processing unit (the "Unit") by Covanta or its affiliate Covanta Metals Marketing, LLC. It is anticipated that the Unit will be operated for a period of up to one (1) year from the commencement of operations at the landfill under this letter agreement.

In recognition that the processing of Ash and reuse of the materials from processed Ash is environmentally sound and will extend the life of the ash landfill, the County agrees to pay Covanta $2.00 for each ton of Ash processed. The Ash tons that will be processed shall not exceed 75,000 tons, unless mutually agreed to by both parties. The County may request the Company stop the work due to safety concerns and or for convenience. The County shall not be responsible to pay any costs of operating or maintaining the Unit, or any other costs relating to the Unit.

<u>Scope of Work</u>

1. Term: 1 year
2. Hours: Monday – Sunday; 6:00AM-6:00PM
3. Insurances: (a) *see* Titan indemnification in Attachment 1
   (b) Covanta to provide Indemnification and Insurances as provided in Attachment 2.

4. Equipment: Mobile Metals Machine
5. Pass Through: The County will pay the Company $2.00 for each ton of Ash processed.
6. Management Fee: No Management fee

Pursuant to Section 7.1.5 of the Agreement, the County requests that the Company begin processing the Ash at the RRF Site, as soon as practicable. The County agrees to (A) make timely payments to the Company, and (B) not to set-off any amounts owed to the Company in connection with such services and (C) to the extent allowed by law, defend and hold harmless the Company for any liabilities, claims or damages, including attorney's fees, the Company may incur in connection with a claim by a third party in connection with the mobile metals processing at the ashfill to remove residues.

The Company agrees to the extent allowed by law, defend and hold the County harmless from any liabilities, costs, claims or damages (including attorneys' fees at the trial and appellate levels) the County may incur in connection with a claim against the County by a third party caused by the negligence or willful misconduct of Company in connection with such services.

MIAMI-DADE COUNTY
Department of Solid Waste Management

Michael J. Fernandez
Director

Dated: 1/27/21

AGREED AND ACCEPTED
Covanta Dade Renewable Energy Ltd.

William Meredith
Business Manager

Dated: 1/28/21

Attachments

c: David Stephen Hope, Assistant County Attorney
Achaya Kelapanda, Assistant Director, Technical Services
Johanna Faddis, Sr. Executive Assistant to the Director

INDEMNITY AGREEMENT

This Indemnity Agreement ("Agreement") is effective as of September 1, 2020 (the "Effective Date") between **Titan Florida LLC** ("Titan") and the **Miami-Dade County** (the "County").

Whereas, the County through its Department of Solid Waste Management has contracted with Covanta Dade Renewable Energy LLC ("Covanta") to process solid waste from the County at Covanta's waste management and energy co-generation facility in Doral, FL (the "Facility");

Whereas, Covanta's process at the Facility generates bottom ash (the "Material") that may be put to beneficial use in Titan's cement production process at Titan's plant in Medley, Florida; and

Whereas, while the parties hereto have no indication that such beneficial use could cause any cement product deficiencies as a result of such beneficial use, to permit the stated beneficial use by Titan, the County requires Titan provide to the County the protections stated herein.

NOW, THEREFORE, in consideration of the mutual promises herein contained, the parties agree as follows:

1. **Indemnity.**
   a. Titan shall indemnify, defend, and hold harmless the County and its officers, employees, agents and instrumentalities, from all liability, loss, damages, cost and expense (including court costs, cost of defense including appellate proceedings, and reasonable attorneys' fees) arising from third party claims against the County as a result of claims, demands, suits, causes of action or proceedings of any kind or nature arising out of, relating to or resulting from the use by Titan of the Material in Titan's cement products ("Claim"). Notwithstanding the foregoing, Titan's obligations under this Agreement do not include any claims against County by Covanta or any entity that controls, is controlled by, or under common control with, Covanta. For purposes of this Agreement, control means the possession, directly or indirectly, of the power to direct or cause the direction of the management, or has power to vote fifty percent (50%) or more of any class of voting securities, of the subject entity.

   b. Titan's indemnity obligation hereunder is secondary to any insurance made available to it by Covanta.

2. **County Responsibility.** Titan's obligations under this Agreement are contingent on the following:

   a. Nothing in this Agreement shall waive any defense of sovereign immunity by County under Florida Statutes Section 768.28 (or any similar statute, order, decree or act of legislative body), including but not limited to any limitations on liability, any statute of limitations, and any limitation on attorneys' fees. With respect to any Claim for which County seeks indemnity hereunder, County must exercise, and not waive without the prior written consent of Titan, the defense of sovereign immunity, and any and all defenses of which it may avail itself.

   b. County must give Titan prompt written notice of any Claim for which County seeks indemnity, stating the nature and basis of the Claim, and, to the extent known, the actual or estimated losses claimed thereby. The failure to give such notice timely shall not affect Titan's obligations hereunder except to the extent that Titan is prejudiced by such failure. With respect to any Claim to which Titan has an indemnification obligation, Titan shall have the right to defend such Claim and the County shall render such assistance as may be requested to ensure the adequate defense thereof. No settlement of any Claim may be made by Titan without the County's consent, provided such consent shall not be necessary if the settlement results in an unconditional release of the County without the admission by County of guilt, complicity or culpability.

3. **Notice.** County shall give Titan written notice as required in Section 2 by delivery by a nationally recognized courier service for next business day delivery to:

Titan Florida LLC
Attn. Zaklina Stamboliska, Vice President
455 Fairway Drive
Deerfield Beach, FL 33441

With a copy to:
Titan America LLC
Attn: Legal Dept.
5700 Lake Wright Drive, Suite 300
Norfolk, VA 23502

4. Term. This Agreement shall be in effect as of the Effective Date and shall terminate five (5) years from the last date in which Titan incorporates the Materials in its cement products or the statute of limitations to file such Claim(s) expires, whichever is longer, according to Titan's production and inventory records.

5. Governing Law. This Agreement shall be governed in accordance with the laws of the State of Florida without giving effect to any choice or conflicts of law. Venue shall be in Miami-Dade County.

Titan Florida LLC

By: ______________________
Zaklina Stamboliska, Vice President

Date: September 18, 2020

Miami-Dade County

By: ______________________

Name: Michael Fernandez

Title: Director

Date: SeptemberXX,2020 January 27, 2021

Approved for legal sufficiency

____
Assistant County Attorney

2

INDEMNIFICATION AND INSURANCE

Contractor shall indemnify and hold harmless the County and its officers, employees, agents and instrumentalities from any and all liability, losses or damages, including attorneys' fees and costs of defense, which the County or its officers, employees, agents or instrumentalities may incur as a result of claims, demands, suits, causes of actions or proceedings of any kind or nature arising out of, relating to or resulting from the performance of this Agreement by the Contractor or its employees, agents, servants, partners principals or subcontractors. Contractor shall pay all claims and losses in connection therewith and shall investigate and defend all claims, suits or actions of any kind or nature in the name of the County, where applicable, including appellate proceedings, and shall pay all costs, judgments, and attorney's fees which may issue thereon. Contractor expressly understands and agrees that any insurance protection required by this Agreement or otherwise provided by the Contractor shall in no way limit the responsibility to indemnify, keep and save harmless and defend the County or its officers, employees, agents and instrumentalities as herein provided.

The Contractor shall furnish to **the Dept. of Solid Waste Mgmt. 2525 NW 62 St. Miami, FL 33147**, Certificate(s) of Insurance which indicate that insurance coverage has been obtained which meets the requirements as outlined below:

A. Worker's Compensation Insurance for all employees of the Contractor as required by Florida Statute 440.

B. Commercial General Liability Insurance in an amount not less than $1,000,000 per occurrence, and $2,000,000 in the aggregate, not to exclude Products and Completed Operations and Explosion Collapse and Underground Hazards. **Miami-Dade County must be shown as an additional insured with respect to this coverage.**

C. Automobile Liability Insurance covering all owned, non-owned and hired vehicles used in connection with the work, in an amount not less than $1,000,000 combined single limit per occurrence for bodily injury and property damage.

D. Pollution Liability Coverage in an amount not less than $2,000,000 per occurrence

E. Professional Liability Insurance in an amount not less than $2,000,000 per claim.

F. Umbrella Liability Insurance in an amount not less than $5,000,000 per occurrence, and $5,000,000 in the aggregate.

   a. If Excess Liability is provided must be follow form for coverage's B and C.

All insurance policies required above shall be issued by companies authorized to do business under the laws of the State of Florida, with the following qualifications:

The company must be rated no less than "**A-**" as to management, and no less than "Class **VII**" as to financial strength, by Best's Insurance Guide, published by A.M. Best Company, Oldwick, New Jersey, or its equivalent, subject to the approval of the County Risk Management Division.

or

The company must hold a valid Florida Certificate of Authority as shown in the latest "List of All Insurance Companies Authorized or Approved to Do Business in Florida" issued by the State of Florida Department of Financial Services.

NOTE: CERTIFICATE HOLDER MUST READ:

MIAMI-DADE COUNTY
111 NW 1st STREET
SUITE 2340
MIAMI, FL 33128

ACORD®

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY): 1/13/2021

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER
Arthur J. Gallagher Risk Management Services, Inc.
250 Park Avenue
3rd Floor
New York NY 10177

CONTACT NAME: Wanda Hernandez-Rivas
PHONE (A/C, No, Ext): 212-994-7100 | FAX (A/C, No): 212-994-7047
E-MAIL ADDRESS: wanda.rivas@ajg.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : ACE American Insurance Company	22667
INSURER B : Indemnity Insurance Company of N A	43575
INSURER C : ACE Property & Casualty Insurance Co	20699
INSURER D :	
INSURER E :	
INSURER F :	

INSURED COVAENE-04
Covanta Dade Renewable Energy Ltd.
6990 N. W. 97th Ave
Miami, FL 33178

COVERAGES **CERTIFICATE NUMBER:** 1388188734 **REVISION NUMBER:**

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY	Y		HDO G71448952	10/20/2020	10/20/2021	EACH OCCURRENCE	$ 2,000,000
	CLAIMS-MADE X OCCUR						DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 1,000,000
							MED EXP (Any one person)	$ 50,000
							PERSONAL & ADV INJURY	$ 2,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$ 2,000,000
	X POLICY PRO-JECT LOC						PRODUCTS - COMP/OP AGG	$ 2,000,000
	OTHER:							$
A	AUTOMOBILE LIABILITY			ISA H25307392	10/20/2020	10/20/2021	COMBINED SINGLE LIMIT (Ea accident)	$ 2,000,000
	X ANY AUTO						BODILY INJURY (Per person)	$
	OWNED AUTOS ONLY / SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS ONLY / NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
								$
C	X UMBRELLA LIAB X OCCUR			XOO G71751247 002	10/20/2020	10/20/2021	EACH OCCURRENCE	$ 5,000,000
	EXCESS LIAB CLAIMS-MADE						AGGREGATE	$ 5,000,000
	DED X RETENTION $ 25,000 SIR							$
B	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N			WLR C67461927 (AOS)	10/20/2020	10/20/2021	X PER STATUTE / OTH-ER	
	ANYPROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH)	N / A					E.L. EACH ACCIDENT	$ 1,000,000
	If yes, describe under DESCRIPTION OF OPERATIONS below						E.L. DISEASE - EA EMPLOYEE	$ 1,000,000
							E.L. DISEASE - POLICY LIMIT	$ 1,000,000
A	Pollution Liability			PPL G58141902 001	10/19/2017	2/16/2021	BI/PD/Remediation	$2,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
Miami-Dade County is included as Additional Insured A.T.I.M.A. as required by written contract, pursuant to and subject to the policy's terms, definitions, conditions and exclusions.

CERTIFICATE HOLDER

MIAMI-DADE COUNTY
111 NW 1st STREET
SUITE 2340
MIAMI FL 33128

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

AUTHORIZED REPRESENTATIVE

FLORIDA DEPARTMENT OF Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Ron DeSantis
Governor

Jeanette Nuñez
Lt. Governor

Shawn Hamilton
Secretary

December 21, 2021

Sent by Electronic Mail – Document Access Verification Requested

Achaya Kelapanda
Assistant Director, Technical Services
Miami-Dade County Department of Solid Waste Management
Dr. Martin Luther King, Jr. Office Plaza
25252 N. W. 62nd Street, 5th Floor
Miami, Florida 33147
Achaya.Kelapanda@miamidade.gov

RE: Miami-Dade County Resource Recovery Facility (PA77-08)
Request for Time Extension for Amendment (AM20-218)
Mobile Metals Recovery System

Dear Mr. Kelapanda:

On July 16, 2020, the Department of Environmental Protection's Siting Coordination Office (Department) approved Miami-Dade County Department of Solid Waste Management's request dated April 24, 2020, for a post certification amendment to the Miami-Dade County Resource Recovery Facility's (MDCRRF's) Site Certification Application (see attached). The amendment request was to obtain approval for the temporary operation of a Mobile Metals Recovery System at the MDCRRF site monofill for a period of 12 months.

The facility began operation of the pilot project on February 10, 2021. On November 8, 2021, the Department received a request from Miami-Dade County Department of Solid Waste Management to extend the approved time period of the temporary operation of the Mobile Metals Recovery System for an additional 12 months.

The Department has no objections to the requested extension provided that Miami-Dade County continues to comply with the requirements set forth in the Conditions of Certification. By this letter, the Department grants approval of the temporary operation of a Mobile Metals Recovery System at the MDCRRF site monofill for an additional 12-month period to February 10, 2023. No other changes are authorized, and all previous and existing requirements apply. This letter should be attached to the Department's July 16, 2020 approval and made available for on-site review by those agencies with regulatory authority.

Any questions regarding the Department's review of your post-certification amendment should be directed to Ann Seiler (850)717-9113 or Nate Senn at (850)717-9111. Questions regarding legal issues should be referred to the Department's Office of General Counsel at (850)245-2257.

Sincerely,

Cindy Mulkey
Program Administrator
Siting Coordination Office

Attachment: Department's Amendment Approval dated July 16, 2020

CC by EMAIL:
Kelley Boatwright, DEP SWD Director: Kelley.M.Boatwright@FloridaDEP.gov
Greg Alba, DEP SWD: Greg.Alba@FloridaDEP.gov
Elizabeth Kromhout, DEP Solid Waste: Elizabeth.Kromhout@FloridaDEP.gov

FILING AND ACKNOWLEDGEMENT

FILED, on this date, pursuant to s.120.52 Florida Statutes, with the designated Department Clerk, receipt of which is Hereby acknowledged.

________________________ ______________
Clerk Date

Service List: CC by email (Document Access Verification Requested)

Michael Weiss, Esquire
Department of Environmental Protection
3900 Commonwealth Blvd., M.S. 35
Tallahassee, Florida 32399-3000
michael.weiss@dep.state.fl.us

Lee Eng Tan, Esquire
Florida Public Service Commission
Office of General Counsel
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Tallahassee, Florida 32399-0850
LTan@psc.state.fl.us

Richard Shine, Esquire
Jasmin Raffington
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Richard.Shine2@dot.state.fl.us
jasmin.raffington@dot.state.fl.us
April.combs@dot.state.fl.us

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Florida Fish & Wildlife Conservation Commission
620 South Meridian Street
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Emily.Norton@MyFWC.com
ConservationPlanningServices@myfwc.com

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ejohnson@sfwmd.gov

Valerie Wright, Esquire
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Scott.Rogers@deo.myflorida.com

Jon Morris, Esquire
Department of State - DHR
R.A. Gray Building 4th Floor
500 South Bronough Street
Tallahassee, Florida 32399-0250
jon.morris@dos.myflorida.com

Robert A. Cuevas, Esquire
Miami-Dade County
County Attorney
111 Northwest First Street
Suite 2810
Miami, Florida 33128
atty@miamidade.gov
Christine.Velazquez@miamidade.gov
Lee.Hefty@miamidade.gov

MEMORANDUM

(Revised)

TO: Honorable Chairman Jose "Pepe" Diaz and Members, Board of County Commissioners

DATE: May 3, 2022

FROM: Geri Bonzon-Keenan
County Attorney

SUBJECT: Agenda Item No. 8(M)(1)

Please note any items checked.

_______ **"3-Day Rule" for committees applicable if raised**

_______ **6 weeks required between first reading and public hearing**

_______ **4 weeks notification to municipal officials required prior to public hearing**

_______ **Decreases revenues or increases expenditures without balancing budget**

_______ **Budget required**

_______ **Statement of fiscal impact required**

_______ **Statement of social equity required**

_______ **Ordinance creating a new board requires detailed County Mayor's report for public hearing**

_______ **No committee review**

_______ **Applicable legislation requires more than a majority vote (i.e., 2/3's present ____, 2/3 membership ____, 3/5's ____, unanimous ____, CDMP 7 vote requirement per 2-116.1(3)(h) or (4)(c) ____, CDMP 2/3 vote requirement per 2-116.1(3)(h) or (4)(c) ____, or CDMP 9 vote requirement per 2-116.1(4)(c)(2) ____) to approve**

_______ **Current information regarding funding source, index code and available balance, and available capacity (if debt is contemplated) required**

Approved ________________________ Mayor

Veto __________

Override __________

Agenda Item No. 8(M)(1)
5-3-22

RESOLUTION NO. ________________________

RESOLUTION AUTHORIZING THE COUNTY MAYOR OR COUNTY MAYOR'S DESIGNEE TO EXTEND THE ASH REUSE PILOT STUDY PROJECT AND CONTINUE THE AGREEMENT BETWEEN THE DEPARTMENT OF SOLID WASTE MANAGEMENT AND COVANTA DADE RENEWABLE ENERGY LTD., TO PROCESS ASH FROM THE RESOURCES RECOVERY FACILITY TO BE REUSED FOR BENEFICIAL PURPOSES AS A MATERIAL SUBSTITUTE IN THE PRODUCTION OF CEMENT, EXTEND THE AGREEMENT BY 12 MONTHS DUE TO COVID-RELATED DELAYS, AND PROVIDE A REPORT ON THE STUDY

WHEREAS, the Board desires to accomplish the purposes outlined in the accompanying memorandum, a copy of which is incorporated by reference; and

WHEREAS, the County owns the Resources Recovery Facility ("RRF") located at 6990 NW 97th Avenue, Doral, Florida, which produces ash as a byproduct that must be disposed of in a lined landfill; and

WHEREAS, on March 8, 2016, the Board of County Commissioners passed and adopted Resolution No. R-213-16, which approved a research project with the University of Florida ("UF") Department of Environmental Engineering Sciences, Engineering School of Sustainable Infrastructure and Environment and the Hinkley Center for Solid and Hazardous Waste Management to determine the suitability of bottom ash substitute in cement and cement products; and

WHEREAS, the UF research project found that the ash produced at the RRF is a suitable substitute for coal ash in the production of cement, thereby creating an opportunity to recycle the ash and eliminate the cost of disposal; and

WHEREAS, the results of the research project have been presented to the Florida Department of Environmental Protection ("FDEP") along with the positive results of a test batch from Titan Florida LLC ("Titan"); and

WHEREAS, on July 15, 2020, FDEP advised the Department of Solid Waste Management ("DSWM"), that it had no objections to a 12-month pilot study and on December 21, 2021, FDEP approved a 12-month extension; and

WHEREAS, in order to evaluate the feasibility of reusing the ash for beneficial purposes, the County agreed to make a portion of the ash landfill at the RRF, (the "Facility Site") available to Covanta for operation of a mobile metals processing unit (the "Unit") by Covanta Dade Renewable Energy Ltd. ("Covanta"), or its affiliate Covanta Metals Marketing, LLC (the "Agreement"); and

WHEREAS, it is anticipated that the Unit will continue to be operated for an additional period of up to one year from the execution of the extension,

NOW, THEREFORE, BE IT RESOLVED BY THE BOARD OF COUNTY COMMISSIONERS OF MIAMI-DADE COUNTY, FLORIDA, that this Board authorizes the County Mayor or County Mayor's designee to extend the Ash Reuse Pilot Study Project and continue the Agreement between the DSWM and Covanta, to process ash from the County's RRF, to be reused for beneficial purposes as a material substitute in the production of cement and extend the Agreement for 12 months due to COVID-related delays. The County Mayor or County Mayor's designee shall provide a report to the Board on the long-term viability of the project within 455 days of the effective date of this resolution. Such report shall be placed on an agenda of the full Board without committee review in accordance with Ordinance No. 14-65.

The foregoing resolution was offered by Commissioner ,
who moved its adoption. The motion was seconded by Commissioner
and upon being put to a vote, the vote was as follows:

Jose "Pepe" Diaz, Chairman
Oliver G. Gilbert, III, Vice-Chairman

Sen. René García	Keon Hardemon
Sally A. Heyman	Danielle Cohen Higgins
Eileen Higgins	Joe A. Martinez
Kionne L. McGhee	Jean Monestime
Raquel A. Regalado	Rebeca Sosa
Sen. Javier D. Souto	

The Chairperson thereupon declared this resolution duly passed and adopted this 3rd day of May, 2022. This resolution shall become effective upon the earlier of (1) 10 days after the date of its adoption unless vetoed by the County Mayor, and if vetoed, shall become effective only upon an override by this Board, or (2) approval by the County Mayor of this resolution and the filing of this approval with the Clerk of the Board.

MIAMI-DADE COUNTY, FLORIDA
BY ITS BOARD OF
COUNTY COMMISSIONERS

HARVEY RUVIN, CLERK

By:________________________
Deputy Clerk

Approved by County Attorney as
to form and legal sufficiency.

David Stephen Hope