UTILIZATION OF INCINERATOR BOTTOM ASH RESIDUES: PROCESS CONSIDERATIONS AND FIELD MANAGEMENT REQUIREMENTS

KEITH E. FORRESTER
Forrester Environmental Services, Inc.
Stratham, New Hampshire

ABSTRACT

This paper presents the process considerations and field management requirements relative to the use of municipal solid waste incinerator ash from the boiler grate section only, hereafter referred to as Bottom Ash (BA). The ash handling and management considerations and requirements discussed within the paper would apply to most incineration or power production operations which produce a BA, including coal, refuse and wood as well as non-fuels such as petroleum contaminated soils, hazardous inorganic bearing wastes and medical wastes incinerated for organics destruction.

The BA production process considerations include separation, flyash (FA) and/or flyash scrubber residue (FASR) separate management, stabilization and disposal and BA processing, storage and transport. The BA use and field management requirements will often be regulated under state and/or federal solid waste rules, and would consider BA end-use engineering objectives and health risk evaluations.

The production considerations and end-use requirements presented herein reveal that BA use is viable, yet requires attention to generator process controls and modifications, stabilization of FA/FASR and appropriate evaluation and control of the BA use in the uncontrolled environment.

NOMENCLATURE

BA	Bottom ash residues from incinerator facilities
FA	Flyash from air pollution control capture
FASR	Flyash mixed with scrubbing products such as lime
TCLP	Federal RCRA hazardous waste leaching test
RTE	Refuse-to-Energy
MWEP	Municipal Waste Extraction Procedure
FESI	Forrester Environmental Services, Inc.
CA	Combined Ash from RTE facilities
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act

CURRENT ASH MANAGEMENT GENERATION, ISSUES AND PRACTICE

Refuse-to-Energy Ash Production and Type

Refuse-To-Energy (RTE) facilities employ a form of recycling, involving the use of solid waste as a fuel to produce steam which in turn produces electricity. Currently, 128 plants convert 14% of the nation's refuse into energy annually [4]. The U.S. EPA's Agenda for Action has set a goal of doubling the amount of RTE projects within the next few years, thus doubling the amount of ash residue to be handled, used and/or disposed as well. In the process of combusting refuse for energy, the total volume of waste is reduced by 90%, resulting in an ash generation volume of near 10% by volume and 30% by weight.

Residue Types. In most modern RTE facilities, refuse is combusted at temperatures approaching 1800 to 2500 degrees Fahrenheit. Many materials originally present in the solid waste prior to combustion are substantially reduced or destroyed. Non-combustible material such as iron, aluminum, calcium, sodium and silicates make up the major components of ash residue (Forrester, 1989).

The ash residues are collected at various points in the system, producing two distinctive types — "bottom ash" and "fly ash". As the words imply, bottom ash is collected at the bottom of the furnace grates following the combustion process. Flyash is composed of small particles which are carried by the combustion flue gas and then captured by the air pollution control devices. Bottom ash typically represents roughly 85 to 90 percent by weight of the total ash produced in a mass burn facility, with flyash and "scrubber residues" comprising the remaining 10 to 15 percent ("scrubbers" are combustion gas cleaning systems that neutralize acid gases). The BA/FA ratio for Refuse-Derived Fuel combustion facilities which remove a fraction of ferrous, non-ferrous and certain non-combustible wastes prior to combustion is usually 50/50.

The use of scrubbers significantly alters the leachability of FA by increasing Pb solubility and decreasing Cd solubility based upon the classic metal pH-log solubility characteristics of those elements and compounds thereof.

Current Ash Management

Most commonly, FA/FASR and BA are combined at the trash-to-energy facility and transported to permanent disposal sites. BA is usually wetted in a saturation bath quench system to allow for a boiler air seal and to cool the 1800 to 2500 degree F mass of silica and non-combustibles. The BA is often molten white, and often fractured and highly porous due to sudden cooling in the furnace seal water bath.

FA and FASR are bone dry as generated from air pollution control devices after scrubbing towers, and are collected in enclosed hoppers due to their fugitivity and related human exposure risk. These FA/FASR residues are often wetted to control dusting, and thereafter added to the BA for disposal, thus producing a combined ash (CA).

Since the United States lags European countries in using this combined ash (Hartlen, 1988), landfill disposal was the simplest and most cost effective method of disposing both BA and FA/FASR. The preferred practice is to dispose of the residue at the residue-only landfill, referred to as a "monofill". Similar in design to modern solid waste landfills, ash monofills incorporate liners and leachate collection systems to collect any water that might run off and percolate through the residue. Collected leachate is tested before it is discharged to surface water or sewers. The liners and leachate collection systems are designed to prevent the uncontrolled release of leachate into any neighboring groundwater, surface water or sewer system. Groundwater monitoring wells are installed to monitor and insure performance of the liners and leachate collection systems.

Residue Composition

The composition of the residue from RTE plants is, to a large degree, a reflection of the original waste fuel (Forrester, 1989). The conversion of solid waste to energy destroys many household hazardous substances which were originally in the waste such as cleaners and solvents.

Non-combustible fractions which include metals, such as zinc, lead, cadmium, and mercury tend to be concentrated in the FA/FASR residue. These metals are present in a variety of materials which are currently being disposed of in solid waste landfills. For example, cadmium is used in plastics, printing inks and small rechargeable batteries. Lead is also found in certain plastics, as well as in paints and insecticides. Mercury is found in paints, batteries, and fluorescent light fixtures (Germanas, 1991).

CA Disposal and BA Use Environmental Concerns

Claims that ash residue is dangerous have been used to attempt to block the development of new RTE facilities residue monofills and ash use. Opponents of RTE technology claim that because residue contains materials such as lead, cadmium, and other substances, it should be deemed a "hazardous waste" and disposed of according to the EPA's hazardous waste disposal standards or at the least subject to TCLP testing and applicable regulation under RCRA if the ash exceeds the TCLP limits. The debate over the applicability of TCLP to RTE ash remains ongoing and is currently pending a Supreme Court ruling.

RTE opponents argue that: (a) heavy metals contained in residue are concentrated at unacceptable levels and (b) the metals are "leachable components" which have the potential to reach groundwater supplies. "Leachable components" are those elements or compounds which have the potential to dissolve in water. Critics claim that as rainfall percolates through residue, it has the potential to leach these heavy metals and transport them into the water supply.

However, scientific tests throughout the international community have demonstrated that CA from modern trash-to-energy facilities, when properly managed (including BA reuse applications), does not leach these materials at significant levels. In fact, tests on CA leachate closely "resembles seawater" (Hartlen, 1988) (Roffman, 1990). As a matter of extra safety, these CA leachates are often collected and treated prior to discharge in accordance with strict environmental standards.

BA use demonstrations in Sweden, Germany, Denmark, The Netherlands and the U.S., have revealed no adverse impact on the environment in which they have been used (Hartlen, 1988). These studies have evaluated leachable and total element concentrations of BA and found such to be even more benign than leachate from combined ash which resembles seawater. The USEPA is also concluding a four-year study on ash stabilization using BA and combined residues. This study, to be released in 1993, continues previous EPA studies in 1988 and 1990 which looked at the leachability and content of BA, FA/FASR and CA. The results of these studies have all been very promising, revealing BA to be an aggregate source worth further investigation and use (Wiles, 1993).

THE SPLIT DECISION — BA vs CA

With the results of BA and CA studies showing suitability of use under controlled conditions, one logically asks why would there be any advantage to the separation of BA from FA/FASR, and thus the need for separate handling and ash processing.

The reasoning is found within the same reports, studies and experience which support both BA and CA use. Reports by the USEPA, industry and researchers and experience by the author have shown the FA/FASR component to exhibit the highest levels of fugitivity, solubility and relative exposure risk. Accordingly, the separation of FA/FASR from BA and the direct controlled stabilization and landfilling of FA/FASR is a logical "first step" towards ash use, thus allowing for the use of BA without concerns over the more bioavailable and potentially toxic FA/FASR fraction escaping into the environment. Under this approach, the lowest risk use can be field demonstrated and evaluated, prior to the possible 100% use of all ash residues.

Although there exists FA/FASR use options which provide for considerable end-use control of compositional metals, the BA use has an inherent control of salts, Pb, Cd, Hg, PCDD, PCDF, radionuclides and related exposure risks given its semi-vitrified and glassy characteristics. In all routes (inhalation, ingestion, dermal) of exposure reduction, the BA is a superior product to CA or FA/FASR.

SEPARATION, STABILIZATION AND MANAGEMENT OF FA/FASR

FA/FASR Separation

The separation of flyash FA/FASR from BA will often involve the modification of the facility ash handling systems and the implementation of a flyash stabilization process. Most existing coal, medical waste, hazardous waste and refuse incinerators combine the grate BA with the FA/FASR prior to total ash disposal.

The most common practice within RTE facilities is to combine bottom ash with flyash, thus lowering the fugitivity of the FA/FASR and avoiding the need for a separate ash stabilization and handling process.

In order to produce a BA for end-use, the facility boiler FA (BFA), economizer FA (EFA), superheater FA (SFA), and air pollution control FASR or FA (APCFA) will have to be handled and managed separate from the BA quenching system. This will require reversal of most existing BFA, SFA and EFA systems used in industry today, although such a screw or drag chain reversal is often completed with minor system modifications. Most systems currently used can be "motor-reversed" with use of the existing conveying equipment. The existing equipment will have to be modified in order to provide for a EFA, BFA, SFA collector, as these FA residues were previously collected in the BA quench system.

Most APCFA systems are operated and designed as separate from BA quenching, and combine the APCFA onto a BA conveyor or drag after the BA quench.

Such a APCFA system is easily modified to a separate load-out with use of screw or belt transfers receiving FA/FASR after a bypass down-chute from the APC hoppers.

FA/FASR Stabilization

Stabilization of FA/FASR, for both fugitivity and leachability, should be implemented in order to ensure for safe and manageable FA/FASR handling as compared to the previously mixed and less fugitive combined ash residue.

The stabilization of FA/FASR to pass regulatory tests such as the TCLP or MWEP will be specific to state regulation, as the current EPA position considers RTE ash residues exempt from RCRA. Although the current EPA position exempts ash residues, RTE ash has yet to be considered under the CERCLA Bevill exemption, and thus incinerator ash producers still maintain Superfund liability as compared to disposal of coal and oil ashes which are exempt under CERCLA.

The primary objective of FA/FASR stabilization would be to reduce fugitivity, thus allowing for reasonably safe handling, transport and landfilling. It is important to recognize that the FA/FASR stream presents a clear hazard to workers and the environment, and that such hazard can be reduced and controlled only with proper processing and management. Mismanagement of FA/FASR, such as disposal in unlined landfills, could easily result in direct biotoxicity and direct routes of significant long-term human and biological ingestion exposure due to heavy metal and salts leachability into groundwater. Mismanagement of FA/FASR during handling could as well result in direct worker inhalation and dermal acute and long-term trauma, primarily due to Pb exposure.

There exists a distinct advantage to the separation and handling of FA/FASR with this relative risk in mind. Since the FA/FASR is only 10% to 15% of the total ash stream weight from mass burn facilities, the greatest amount of control and management will then be applied onto the lowest fraction of ash. From a cost perspective, this is desirable. From an exposure potential, this fact is extremely valuable, as the lower the amount of material produced that is high in potential risk, the lower the overall mass of risk to the environment.

This philosophy of waste management is very sound, and is the basis to all forms of toxic material concentration and special stabilization application prior to disposal. Accordingly, the BA separation from FA/FASR is in direct contrast with the "dilution is the solution to pollution" basis. The classical dilution approach is often shortsighted and inconsiderate of long-term biological and environmental accumulation of fractional pollutant loads. In the case of mass burn facility FA/FASR dilution with BA, the FA/FASR exposure is actually increased since the FA/FASR now has near ten times the ability to become fugitive, leach and be contacted through dermal means given the larger area of potential exposure during handling, transport and landfilling.

Methods of FA/FASR Stabilization. There exists a wide variety of FA/FASR stabilization methods. Most methods employed to date, such the FESI and Rolite methods, are proprietary, and balance cost versus short-term and long-term risk from inhalation to leachability. This subject and supporting testing and field results are extensive, and not within the scope potential of this report. FA/FASR stabilization and management systems within the facility as well as in the field should be coordinated and engineered with great care, and by a registered professional engineer skilled in the field. The relative risks and consequence of human and/or environmental damage far outweigh the expense of good engineering and design at the onset of FA/FASR separation.

FA/FASR Management

Except for a limited few controlled uses of FA/FASR, the sound approach to FA/FASR management concludes with a lined and monitored ash monofill. A discussion of appropriate ash monofilling techniques was published by the author (1990).

In general, application of civil engineering methods of moisture control and compaction provide for a superior FA/FASR density and in-situ hydraulic permeability. With proper application and control, a FA/FASR monofill's risk to the environment can be significantly less than that from CA monofills, MSW landfills and even demolition fill sites.

SEPARATION, PROCESSING AND MANAGEMENT OF BA

Separation of BA

The separation of BA requires no process modifications, as BA is the primary and major source of conveyed material at mass burn facilities. The ratio of BA to FA/FASR may vary with various combustors and feed stock, although the same principles of non-modification pertain.

Processing and/or Stabilization of BA

The decision to process and/or stabilize the BA prior to disposal and/or use is highly site specific. The degree of BA processing will most likely be dictated by the end-use client, as well as the initial character of the BA. In all cases, the decision-making and engineering relative to BA processing can be fairly intensive and includes the risk of market fluctuation.

Once processed, the BA is an off-spec commodity, subject to all the difficult and highly volatile economic and political factors which impact any commodity. Being a waste derived commodity, the potential to store and haul on-demand may be further complicated, as storage and transfer actions will most likely be regulated under RCRA, CERCLA and specific state solid waste provisions.

At the minimum, BA would require ferrous scrap removal and size reduction in order to allow for ease of transport and direct reuse as aggregate. A facility operator may wish to contract such processing from a full service ash processing and reuse corporation, or engineer, construct and operate such a process at the tail-end of the RTE facility. Most BA processing methods and applications involve extensive engineering, and should be contracted to a licensed professional engineering firm specializing in ash handling and processing.

Stabilization to pass regulatory tests will, as with FA/FASR, remain a state regulatory issue. There may exist, however, a unique burden to the use of untreated BA in the form of the political and environmental issue. Several RTE projects to date have moved to a decision of BA treatment regardless of the USEPA decision in order to assure that the BA will always pass TCLP and that an additional level of safety is provided to the public, the environment and the shareholders. Remember that BA use is not exempt under the Bevill position, and thus subject to CERCLA regulation and control in the event of a BA "environmental release" and subsequent Superfund action.

Bottom Ash Management

The management of BA, unprocessed or processed, will most often remain as simple as moving a semi-wet aggregate. Exposure risks such as fugitivity are quite low, and focus from regulators will remain primarily on the leachability of salts from the initial surge of Ca, SO4, and Na. BA disposal or storage could be easily managed in a single lined landfill or on a lined pad in order to collect the salt leachate.

BA disposal should avoid use of daily cover, as this may interfere with future BA mining operations. A discussion of BA landfilling methods is covered in a paper on state-of-the art ash landfilling techniques by the author (1989).

Bottom Ash Use History. The beneficial use of BA has been successfully demonstrated throughout the world for coals, wood, oils and refuse. From the streets of Paris to the roads of Nashville, gravel-like BA has been put to beneficial reuse with great success (Hartlen, 1988).

In contrast to unfounded concerns of some environmental groups, many engineers and scientists whom make the study of the environment their career consider BA a viable aggregate for various construction uses. International ash experts and researchers have expressed this opinion on many occasions including recent ash conferences, international workshops, EPA conferences and amongst EPA committees (Wiles, 1993).

Although the full scale use of BA has been found suitable outside the United States, academic institutions and agencies are conducting elaborate demonstrations of BA use in various states. These demonstrations are focusing on confirming the engineering and environment suitability of BA use.

Bottom Ash Use Considerations

The following core points should be considered and evaluated before you begin your BA use program. As each BA use program is site specific, there may exist other regulatory, financial, political, commodity restriction and corporate policy issues which also impact the viability of BA use:

The Marketability of BA and The Aggregate Competition. The sudden production of significant daily BA aggregate production in a region will create competition for local aggregate pricing unless the ability to export BA aggregate is available. Rail and ship export have been evaluated, and in some cases these options can be highly viable.

A local use of BA as an aggregate substitute is most desirable, but is often limited in tonnage, thus resulting in some significant BA storage and handling problems.

As a waste product, on-site or off-site storage for waste use equalization can be risky, since regulations usually require BA use within three to six months or the BA is deemed a waste and subject to such regulations and disposal requirements. Processing BA for end-use should, therefore, consider market demand and be designed to respond to the increase or decrease of such on a real time basis. With most large RTE facilities, the ability to produce BA is not the concern — the ability to bypass untreated BA directly to a backup landfill thus remains as the cost burden, as with current BA handling.

Facility Financial Restrictions. The separation of BA and FA/FASR, the stabilization and separate monofilling of FA/FASR, the stabilization and processing of BA and the maintenance of backup BA landfill contracts or monofill operations will surely require expense today, well before the financial, political and environmental returns of tomorrow. Although there is clearly a CA disposal and CERCLA liability avoided cost incentive, the expectation of BA use and or sales involves risks as stated above.

Management of Alternative Superfund Liabilities. BA use will convert the CERCLA risk of unprocessed BA mixed with unprocessed FA/FASR in your existing CA disposal landfill, to the CERCLA risk of stabilized and field processed FA/FASR in a monofill or monocell and stabilized and processed BA within a civil engineering use outside of a landfill environment or as a cover material. The combinations of risk potentials here can be extensive, and are best considered on a site specific and use basis.

Whether there is an increase or decrease of CERCLA liability relative to BA use and FA/FASR stabilization will depend on the extent of BA use outside of the landfill, the current CA landfill conditions and existing CERCLA liability, the level of control and management employed with BA use and the methods of FA/FASR landfill management employed.

The Political and Regulatory Climate. This last consideration is often the dictating and controlling issue, as BA use will surely not be allowed within respective states unless the state environmental departments and associated political entities accept the scientific and emotional basis for waste BA use.

Although many of the BA producing corporations lobby for BA to be regulated as other natural aggregate, the regulatory reality of today and the expected future is that BA will always be considered a waste product aggregate. Given the heavy metal and salts content of BA as compared to natural aggregate, such a characterization is reasonable (Forrester, 1989).

There are currently several states which allow BA use in restricted applications, such as Florida and Tennessee. With the publication of the 1993 USEPA Ash Stabilization and Solidification Committee Report, and the ongoing USEPA, DOE, NHDES, NJDEP, NYDEC and LIRPC ash use projects as well as those funded by the major RTE vendors, there should be a gradual acceptance of BA use on a state-by-state basis throughout the US within the next five years.

Given the continued debate in the US Congress over ash regulation and use legislation, the appointment of Ms. Carol Browner as USEPA Administrator and the clear record of Vice President Gore against incineration operations, the future of federal BA use allowance is less optimistic. Ms. Browner has a record of being anti-incineration, and was influential in delaying stabilized BA use programs in Florida where she acted as the FLDER Commissioner. Vice President Gore also has a history of opposing incineration operations, and is expected to support Ms. Browner in delaying the development of BA use regulations as intended to be developed by the USEPA under various congressional draft bills.

CONCLUSIONS

There exists a clear and growing body of scientific evidence that bottom ash residue from modern trash-to-energy facilities can be used as a waste aggregate under controlled conditions. Although such scientific evidence exists, the concept of BA use has and continues to be approached by regulators and politicians with caution.

The engineering methods and process modifications required for BA production and separate FA/FASR handling have been evaluated and put to practice in first and second generation field applications. The degree of BA and FA/FASR processing will most often depend on facility budget, site and market conditions. The allowance of BA use will surely depend upon the level of education and political effort brought to bear by the BA producer(s) within that state.

With minor modifications to FA/FASR handling systems, and possible modifications to BA handling for ferrous, non-ferrous and ash sizing, a processed BA can be produced from the modern RTE facility which is an excellent aggregate substitute. At landfill tipping fees of $35.00 to $120.00 per ton of combined ash, the removal and use of the 90% BA fraction presents significant avoided cost savings, and thus a sound economic incentive to consider BA use and its related capital and operating costs.

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