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INNOVATIONS IN MWC ASH MANAGEMENT

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ABSTRACT

Solid waste managers continuously investigate alternative methods for waste management to meet and improve their practice. As part of this process, innovative management techniques and strategies have been implemented to address a wide range of solid waste issues. In recent years, innovative management strategies have been of particular interest to solid waste officials responsible for the management of municipal waste combustor (MWC) ash.

Historically, ash, a potentially reusable material, has been disposed of in monofill or co-disposal landfills. This practice has become costly to generators in terms of tipping fees and to landfill operators through the depletion of valuable landfill airspace. To address these concerns, solid waste managers in several states, including California, Florida, Pennsylvania, New York, and Tennessee, have implemented beneficial use programs in which ash is reused both within and outside of the landfill environment. To date, primary markets for ash include use as alternative landfill construction materials and as road base structural fill.

While recycling of ash has been studied extensively over the past few decades, the combination of available technologies, the state and federal regulatory framework, and project economics are driving MWC projects to evaluate and, where feasible, implement beneficial use as part of their ash management programs.

KEYWORDS: Municipal Waste Combustor; Ash; Beneficial Use; Recycling; Municipal Solid Waste

INTRODUCTION

Solid waste managers have long investigated opportunities to improve existing solid waste management practices. During the primary growth phase of the waste-to-energy industry in the United States through the 1980s, ash generated from the processing of municipal solid waste (MSW) was and still is largely disposed of in either monofill or co-disposal landfill facilities. This management practice is economically burdensome and requires significant amounts of disposal capacity. In recent years, owners and operators of municipal waste combustors (MWC), as well as federal and state regulatory agencies, have expanded routine solid waste management initiatives for the management of ash to identify, develop, and implement innovative management techniques to improve existing ash management systems.

Municipal solid waste is generally managed as part of an integrated solid waste management system that incorporates waste reduction, reuse/recycling, energy recovery, and landfill disposal. Although unit activities can be, and often are operated separately from other activities in an integrated system, they must be managed as part of the overall system. To operate successful waste management systems, managers need to consider the impact of alternative management strategies on both the unit activity and the overall system.

Approximately 32 million tons of MSW are processed each year by currently operating MWCs. With the inclusion of the estimated 8 million tons of additional capacity expected to come on-line from projects in advanced stages of planning (those that have initiated permitting activities and/or developed construction schedules), annual ash generation in the United States will be expected to reach 12 million tons (Berenyi and Gould, 1993). With such a large residual waste stream to manage, the use of innovative techniques and strategies, including beneficial use programs, will allow solid waste managers to improve both the efficiency of existing ash management programs and the overall integrated waste management system.

BENEFICIAL ASH MANAGEMENT

With the advent of changing regulatory programs, technological advances, and improving economic scenarios, ash managers have begun to look beyond monofill or co-disposal landfilling as the only viable management alternatives for ash. Although ash has consistently passed required waste characterization testing, managers of ash have turned to treatment technologies to reduce the potential of contaminant leaching, primarily lead and cadmium, as a means to protect against the potential liabilities generally associated with landfill disposal. The development of treatment technologies has provided the means to pursue alternative management strategies. However, for beneficial ash management programs to be successful, several issues must be addressed, including:

- *Regulatory* - Beneficial use programs need to address regulatory requirements, including an evaluation of potential environmental risks associated with the intended use of the material, such as fugitive emissions and potential groundwater impacts, and solid waste management planning requirements.

- *Technical* - Beneficial use programs must satisfy applicable engineering requirements and performance specifications for the intended use. In many cases, ash treatment has produced acceptable products.

- *Economic* - Beneficial use programs must be economically viable. Operational cost savings must be great enough to offset historical and regulatory resistance to such programs in order to be an attractive waste management alternative.

Regulatory Issues

The beneficial use of ash in the United States has been somewhat limited due to the lack of regulatory programs on the state level that provide a framework for study, demonstration, and implementation of ash reuse opportunities. In many cases, initial attempts at ash reuse have included the development of regulatory protocols that address the environmental and human health issues historically associated with ash.

Existing ash management practices have recently been influenced by the U. S. Supreme Court's decision in *City of Chicago, et al., v. Environmental Defense Fund,* that ash from MWCs is not covered by Section 3001(i) of the Resource Conservations and Recovery Act (RCRA) - which exempts household hazardous waste from RCRA Subtitle C regulations - and that MWC operators are now required to test and characterize ash in accordance with 40 CFR §261.24 (the Toxicity Characteristic Leaching Procedure (TCLP)) prior to determining an appropriate management method. In its June 1995 guidance document the United States Environmental Protection Agency (USEPA) instituted new testing requirements for ash. All ash is now required to be tested to determine whether or not it is hazardous based on the toxicity characteristic. Separate sources of ash may require independent testing depending upon the configuration of the MWC and what is determined to be the "point of generation" of the ash. Ash determined to be hazardous via the TCLP test is to be managed in accordance with all applicable sections of RCRA Subtitle C regulations (USEPA, 1995).

Since many states had already required waste characterization testing, this decision has had little or no impact on their in-place MWC management practices. Murphy and Rogoff (1994) reported that 26 out of the 32 states with MWCs had required testing prior to the Supreme Court decision, and 21 of those states required testing via the TCLP test. Additionally, the EPA continues to allow management of ash as a combined waste stream if fly ash and bottom ash sources and the point at which they are combined are all within the combustion building. Perhaps of most importance to ash reuse projects, the Supreme Court's decision and subsequent EPA requirements have not resulted in actions that restrict generators' ability to reuse/recycle nonhazardous ash and the beneficial use of nonhazardous ash is to be governed by regulations implemented at the state level.

In the last few years, several states have developed programs that have helped spur the reuse of ash. For example, in Pennsylvania, the Pennsylvania Department of Environmental Protection (PaDEP) Equivalency Review regulations (Title 25 Chapter 271.231 of the Pennsylvania Code) allow for the use of waste materials that meet performance specifications and design requirements as alternative landfill construction material in a specific application. This process has recently been streamlined by PaDEP. Where all equivalency review requests were once considered major modifications to a facility's permit, once an equivalent material is approved, additional applications follow less cumbersome minor modification guidelines. PaDEP's beneficial use permitting program provides a framework for obtaining regulatory approvals (25 Pa Code §271.232) for applications outside of the landfill environment. This program requires the applicant to demonstrate that the proposed use does not adversely impact human health or the environment and that it performs acceptably with respect to engineering properties or other requirements.

Treatment Technologies

Throughout the 1980s, the USEPA Risk Reduction Engineering Laboratory, located in Cincinnati, Ohio, conducted a series of research projects to evaluate several solidification/stabilization alternatives for the treatment and reuse of ash. The treatment processes were evaluated by TCLP, as well as other leaching tests designed to target specific constituent release patterns under varying pH conditions. Test results indicated that the use of selected solidification/stabilization technologies resulted in treated ash products that exhibited consistent physical properties and chemical characteristics. The data further indicated that treated ash products did not release constituents of concern (i.e., heavy metals) in quantities that would result in adverse effects on human health or the environment (Kosson et al., 1993).

Ash treatment technologies are generally classified as either physical/chemical or thermal processes. Physical/chemical treatment methods consist primarily of processes that bind or fix leachable components (i.e., non-ferrous or heavy metals) within a solid matrix. Thermal treatment consists of the application of electrical energy to provide high temperatures to melt the ash, such that when the ash is cooled, a glass-like, or vitrified product is formed. Several of these processes allow for the product to be manufactured or processed into a range of product sizes appropriate for specific applications (e.g., construction aggregates, including road base material, landfill construction materials, and concrete and asphalt aggregate).

Physical/Chemical Ash Treatment. Physical/chemical ash treatment technologies are generally referred to as stabilization or solidification technologies that physically and/or chemically bind the constituents of the ash in a stabilized matrix and minimize the potential of the constituents to migrate from the matrix into the surrounding environment. These technologies typically employ a cleaning step to remove constituents including ferrous metals, unburnt and undesirable materials, and a chemical immobilization step that stabilizes heavy metals, either through chemical stabilization or physical solidification. Typical reactants include Portland cement, lime, and phosphate. Physical/chemical treatment processes have gained popularity with MWC operators and regulators alike. These sound, technically proven processes have been demonstrated to reduce heavy metal leaching and, in some cases, to produce a readily usable commercial product. Table 1 provides a listing of physical/chemical treatment technologies currently used in the management of ash.

Table 1
Currently Operating Ash Treatment Facilities

Vendor/ Operator	*Description*	*Location*	*Estimated Cost †*
American Ash Recycling, Inc.	WES-PHix‡ plus screening/sorting with materials recovery	Nashville, TN	$30-35
Resource Recycling, Inc.	Screening/sorting with materials recovery	Pinellas County, FL	$3-5
Rolite, Inc.	Portland cement addition	Minquadale, DE	$25-35
Wheelabrator Environmental Systems, Inc.	WES-PHix (Phosphoric acid addition)	Installed at more than 20 MWCs in the U.S.	$3-8

† per ton of ash treated
‡ Licensed from Wheelabrator Environmental Systems, Inc.

Thermal Ash Treatment. Thermal ash treatment technologies are based on the application of electric energy in the form of heat to raise the temperature of ash to its melting point and cooling the liquefied ash into a stable, supercooled matrix (glass-like material). The heating and cooling of the ash bonds trace constituents on the atomic level. In 1990, the American Society of Mechanical Engineers and the U.S. Bureau of Mines initiated an investigation of the merits of vitrification as a waste treatment process. In the study, over 54,000 pounds (24,500 kg) of ash and sewage sludge combustor residue was processed. Sixty-nine to 86 percent of the processed ash formed vitreous products, with the remainder forming metallic product, mstte product, and fume, baghouse, and gas solids. TCLP testing of the vitreous products for the eight regulated metals indicated that concentrations were below regulatory limits. Additionally, the vitrified products met the American Society for Testing and Materials (ASTM) requirements for Portland cement and asphaltic concrete aggregates (ASME, 1994).

Despite the positive results, the economic analysis completed as part of the study indicated that vitrification processing costs, estimated to be as high as $200 per ton, may prohibit full-scale implementation. Additional investigations on the operations of full-scale vitrification processes and the realization of more favorable economics may improve the feasibility of vitrification to the waste management industry.

MARKETS

Based on experiences gained from various research projects, regulatory interactions, and demonstration projects, the beneficial use of ash has developed into two markets: (1) alternative landfill construction materials; and (2) substitute sggregates in asphalt and concrete applications and road construction.

Landfill Applications

The beneficial use of ash on state-of-the-art MSW landfills is usually viewed acceptably by the regulatory community given the landfill liner and leachate collection systems associated with these landfills and, hence, the reduced potential for environmental impact. The applicability of this alternative is largely dependent on local and state regulatory interpretation and requirements. The use of ash as an alternative landfill construction material reduces the added expenses of buying and transporting cover materials to the MSW landfill site, while using the ash in a regulated facility. The recycling/reuse of ash in such applications also has the potential to reduce disposal costs incurred by the parties responsible for management of the ash.

In addition to the growing number of full-scale beneficial use programs incorporating ash as alternate landfill construction materials, a recent study completed by the U.S. Department of Energy's National Renewable Energy Laboratory reported that ash exhibited equivalent physical characteristics to those materials routinely accepted as landfill construction material (Jones et al., 1994).

Daily/Intermediate Landfill Cover. The use of ash or treated ash as daily and intermediate cover requires that the material meet certain structural and environmental criteria and is, in general, equivalent to the material being replaced. Specific criteria considered in evaluating ash for cover material include permeability, durability, vector control, and workability of the material. The cover material must also be heavy (i.e., minimal fines content) to avoid airborne transport. Solid waste managers in California, Florida, and Pennsylvania have successfully implemented beneficial use programs utilizing ash as alternate daily cover materials.

Gas Venting Layers in Final Cover. The gas venting layer is designed to allow the migration of gases produced in the landfill into a gas collection system. The gas venting layer must simultaneously allow the migration of landfill gases while providing physical support and stability for other landfill system components that are placed above the gas venting layer during construction of the final cap. Treatment of the ash can modify the physical characteristics of the ash (particle size, porosity, permeability) to improve the usefulness and workability of the ash. The product must also demonstrate chemical resistance to landfill gases. In Islip, NY, treated ash was used as gas venting material as part of closure activities at the acre Blydenburg Landfill.

Other Uses. In addition to use as daily/intermediate cover and as gas venting material, it is expected that ash could be incorporated as part of final cover, leachate collection system drainage layers, subcell berms, and road base material.

Aggregate Substitutes

Asphalt Products. In the 1970s, several studies were conducted by the Federal Highway Administration, substituting untreated bottom ash for natural aggregates (gravel and crushed stone) normally used for road construction. Paved roads and test patches were monitored over time and evaluated for strength, stability and durability. Ash pavement cores and mixes were tested for leaching of regulated metals. Leachates generated for each mixture tested below the regulatory thresholds for regulated metals. Various conclusions were drawn from these test programs and can be summarized as follows:

- Ash can be mixed, placed and compacted using conventional equipment;
- Optimal ash to natural aggregate ratio is 50 : 50;
- Ash should exhibit low organic content (<10 percent);
- Ash can be used in lieu of cement in stabilized base coarse mixtures; and
- Ash pavement cores and mixes, based on the results of TCLP testing, do not appear to be hazardous materials.

Concrete Products. Use of ash in various concrete products has many attractive features from an environmental and engineering standpoint. It has been shown that the chemical reactions that ash is subjected to during concrete curing reduce the leachability of regulated metals. In addition, the physical encapsulation of the ash particles, particularly fines, contributes to reduced leachability.

The existence of many standard testing protocols and specifications for materials to be used in concrete applications and products provide a basis for addressing issues associated with obtaining regulatory approvals. The use of ash as a complete or partial replacement for natural aggregate in concrete mixtures requires that the product exhibit specific criteria for moisture, organic, fines, and glass content. These criteria may affect the curing and stability of the concrete. From a physical standpoint, the product must demonstrate shear and compressive strengths to allow for its use in particular applications. Researchers have indicated that ash aggregate content ranging from 15 to 50 percent have produced concrete products of acceptable physical properties.

The Marine Sciences Research Center, a part of the State University of New York (SUNY) at Stony Brook's Waste Management Institute, has conducted several research programs to investigate the feasibility of incorporating ash in concrete blocks for construction of an artificial reef. Concrete blocks were produced using commercial block forming techniques. Standard concrete blocks, used for the control in the studies, were produced with natural aggregate in the same manner. As part of the SUNY project, the ash blocks and standard blocks were placed in separate artificial reefs in Conscience Bay, Long Island Sound in April 1987. Bench scale tests and monitoring of the artificial reefs over time revealed that the compressive strength of the ash/concrete remained stable or increased. The actual reef study indicated that the metals of concern, namely lead and cadmium, were retained within the matrix; and organisms growing on the surface of the blocks did not accumulate metals (Breslin et al., 1988).

BENEFICIAL USE PROGRAMS

The potential for recycling/reusing ash is enormous. Ash reuse markets have emerged as viable alternatives in New York, Pennsylvania, Tennessee, California, and Florida, where the use of ash in landfill settings or as a component for road construction has been approved. Table 2 provides a summary of selected beneficial use ash programs. As beneficial use alternatives continue to be developed, additional data and experience will be added to the extensive body of information already available. The combination of actual field experience and regulatory oversight should serve to further address the environmental and economic issues associated with the beneficial use of ash. A capsule summary of selected beneficial use ash programs in varying stages of development is provided.

Table 2
Beneficial Use Programs

Location	*Treatment*	*Beneficial Use*
Islip, NY	Rolite, Inc.	Gas venting material
Chester County, PA	Rolite, Inc.	Daily cover material On-site road base material
Pinellas County, FL	WES-PHix and Resource Recycling, Inc.	Daily cover material
Long Beach, CA	WES-PHix	Daily cover material
Nashville, TN	American Ash Recycling, Inc.	Structural fill /road base material

Town of Islip, New York

In Islip, NY, a demonstration project was completed on the bench, pilot, and full-scale levels to assess the chemical characteristics and physical performance of a cement-based ash stabilization technology. The treated ash product was evaluated using TCLP and other leaching tests designed to target specific constituent release patterns under varying pH conditions to assess leaching potential and possible impact to human health and the environment. A number of tests were also performed to evaluate conformance to applicable landfill construction design criteria, including durability (wet-dry cycle tests) and field performance standards such as handling characteristics, permeability, grain size, slope-stability, and in-place density. Results of the demonstration program indicated that treated ash products could be used as landfill construction material, in Islip's case as a gas venting material, and meet established design criteria as well as mitigating potential environmental impacts associated with its use. The NY State Department of Environmental Conservation granted approval to Islip, NY, in 1990 for the use of the treated ash as gas venting layer material in the closure of the Blydenburg Landfill.

Chester County, Pennsylvania

The Chester County Solid Waste Authority (CCSWA) evaluated potential reuse alternatives for a treated ash at the Lanchester Landfill in Honey Brook, Pennsylvania. The goal of the demonstration was to evaluate the chemical and physical characteristics of the treated ash, and evaluate its potential reuse alternatives at the Lanchester Landfill.

The reuse alternatives considered included use of treated ash as daily and intermediate cover, the drainage layer in the construction of new cells, and the gas venting layer of the final cap. Additional applications included structural fill for subcell berm and/or roadbed construction. The criteria used to evaluate the treated ash were the PaDEP Title 25 Regulations and the material specifications identified by the CCSWA. The engineering properties of the treated ash, and how they compare to the PaDEP requirements, were evaluated in a chemical and physical testing demonstration program.

The demonstration program consisted of material sampling, a chemical and physical laboratory characterization, and an in-place field characterization of the treated ash. The chemical characterization utilized data generated during the Islip Resource Recovery Agency Demonstration in Islip, New York, and included additional TCLP testing of the treated ash. The physical characterization, on the other hand, included laboratory and field durability testing, moisture density relationships, degradation in particle size resulting from Proctor compactive effort, volatile organic matter content, the effects weathering and successive wetting and drying cycles have on particle integrity, and the internal shear strength of the treated ash. The results of the evaluation indicated that the treated ash possessed the properties necessary for use as a substitute for daily cover, gas venting layer, and structural fill. In October 1993, PaDEP approved the use of the treated ash during landfill operations as daily cover material and as roadbed material for on-site roads.

In addition to these two ash recycling/reuse projects, there are a number of other programs in active operation or various stages of development around the country, including the following:

Pinellas County, Florida

At Pinellas County, FL, operators of the County resource recovery facility have installed Wheelabrator's WES-PHix system for chemical treatment and Resource Recycling, Inc.'s physical processing system to remove recoverable materials and to provide a uniform material for use as daily cover material at the County landfill.

Long Beach, California

The City of Long Beach has installed Wheelabrator's WES-PHix system for chemical treatment. Following treatment, the ash has been used as daily cover material at the City's landfill.

Nashville, Tennessee

Following a successful demonstration treating ash mined from the Gallatin County monofill, American Ash Recycling, Inc. began processing bottom ash from the Sumner County Resource Authority's Nashville Thermal Processing Facility in 1993. AAR, which utilizes WES-PHix and its own proprietary screening and sorting processes, markets the treated ash product as structural fill for use in road construction.

Camden County, New Jersey

In early 1993, the Pollution Control Financing Authority of Camden County began investigating beneficial use opportunities as an alternative means of ash management and issued a request for proposals for full-service vendors for the recycling or beneficial use of ash. However, proposed project economics were determined not to be feasible at the time. Subsequently, Camden County began sending a portion of its ash to a treatment facility in Delaware. The treated ash product had been used as daily cover material at a landfill in Pennsylvania.

York County, Pennsylvania

The York County Solid Waste and Refuse Authority has been proactive in the development of innovative strategies for ash management. Following a preliminary review of potential ash management alternatives, York County is conducting an evaluation of ash treatment technologies, alternative management options, potential beneficial use markets, and applicable regulatory programs.

WHERE DO WE GO FROM HERE?

Beneficial use options for ash have been slow to emerge as viable waste management alternatives to landfill disposal. The results of numerous public and private investigations into the chemical and physical characteristics of ash, the effects of ash treatment technologies, and the acceptability of ash products as reusable products have been widely reported. Significant technical and analytical data exists that suggest that the beneficial use of ash is viable in selected applications, and successful beneficial use projects have been implemented and are currently operating in several states. However, the solid waste industry, as a whole, has been slow to respond to emerging ash management opportunities. Why has the implementation of beneficial use programs remained gradual? What can be done to increased the acceptance of beneficial use ash management programs? Several factors are at play.

First, as previously mentioned, many states do not have defined regulatory programs that can be applied to the beneficial use of ash, a waste that historically has been subjected to sensitive public and regulatory concerns. In light of apparent shortfalls in regulatory programs, in states where solid waste management officials have been proactive in the development of innovative ash management strategies, like Pennsylvania, regulatory agencies have recognized the potential benefits and have developed regulatory guidelines to assist with the development and implementation of alternative ash management programs.

Secondly, the maturation of applicable technologies has begun to impact this industry only recently. As developing technologies continue to meet and exceed the stringent technical and operational specifications required by the solid waste industry, opportunities for beneficial use will become more readily available. Additionally, as technological advances and acceptance continue, treatment costs are expected to become more competitive.

Potential costs are a third issue of concern. The high cost generally associated with monofill and co-disposal of ash has been a major impetus for the investigation into alternative ash management programs. If the recent trend of decreasing landfill disposal costs continues, alternative ash management programs will need to become more competitive with established management options to remain and to improve their economic viability.

In many cases, particularly with public solid waste management agencies, ash is managed as part of an integrated waste management system. Solid waste managers must consider the cost/benefit of alternative ash management programs with respect to the overall waste management system. The use of innovative strategies will benefit these investigations.

For example, treated ash is utilized as alternate landfill daily cover in several states. State regulators generally require daily cover to be a minimum of 6 inches (0.15 m) in thickness. The solid waste industry has been experiencing a growth in the popularity of foams, slurries, and geosynthetics as alternate daily cover materials. These lower-cost alternatives to the use of soil as daily cover may increase competition for beneficial use programs. Acceptable intermediate cover materials, however, which are generally required to be a minimum of 12 inches (0.30 m) in thickness, have not been subject to competition with alternate materials to the extent that daily cover has. Use of ash as an intermediate cover may provide the opportunity for use of other reusable waste materials, such as sewage sludge, leaf waste, or other organic-laden materials, to meet vegetation requirements. Such coordinated waste management strategies may help alleviate unfavorable economic circumstances as well as boost the success of other activities within an overall solid waste management system. Solid waste managers must continue to strive to identify, develop, and implement innovative strategies for ash management to gain public and regulatory acceptance. As experience and acceptance of reused/recycled ash products increases, beneficial use options for ash management are expected to become more economically viable.

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