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Evaluation of residual waste char and ash from the Tactical Garbage to Energy Refinery

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HIGHLIGHTS

- TGER uses wide range of waste feedstocks into producer gas and ethanol to power a 60 kW generator.
- 30:1 reduction of waste volume, leaving a residue of char and ash.
- Analysis indicates carbonaceous and organic material, with presence of Na, Al, Si, Mg, Ca, and S.
- Data suggest residue char and ash are innocuous and unlikely to pose environmental or health risks.

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ABSTRACT

The Tactical Garbage to Energy Refinery (TGER) is a hybrid waste to energy system which combines advanced fermentation with thermal decomposition to convert mixed waste products such as plastic, cardboard and food waste, into energy. The hybrid design allows TGER to convert a broader range of waste streams into energy than possible with unitary systems. The waste output is in the form of a dry mix of ash and char, with the char to ash ratio being somewhat higher during initial start-up before the system has reached full efficiency. Samples of the residual material were collected from the initial and final runs and these materials were subjected to elemental analysis and morphological characterization. Visually, the general morphology of the samples resembled generic char with particulate sizes in the range of 5–10 μm. Scanning electron microscopy shows the char to be composed primarily of fibers which retain the general morphology of plant-based fibers. In addition to carbonaceous and organic material, energy dispersive X-ray spectroscopy indicates the presence of the elements Na, Al, Si, Mg, Ca and S, with traces of K, Ti, Fe and F. These are present inhomogeneously as either particulate inclusions or surface particles on fibers. Data indicate that the residual ash and char are generally innocuous and unlikely to pose environmental or health risks. Results will be used to determine the applicability of these materials for reuse in, for example, composite construction materials.

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1. Introduction

The Tactical Garbage to Energy Refinery (TGER) (Valdes, 2009) is a waste to energy (WTE) system designed for mobile field use. TGER is a hybrid system which combines advanced fermentation and thermal decomposition to convert a broader range

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of waste products into energy than is possible with existing unitary systems, and produces a blend of high energy ethanol and producer gas which can replace JP-8/diesel in military and civilian generators. Development of the system was driven by a requirement to improve security at military forward operating bases (FOB) by reducing the transportation requirements associated with moving fuel into, and garbage out of, the FOB. The original TGER 1.0 model used a downdraft gasifier for thermal decomposition and, when field tested in Iraq under operational conditions at an FOB, was limited to a waste stream with no more than 10% plastic. The second generation TGER 2.0 system substituted an augured horizontal gasifier that was much more efficient in decomposing solid waste and could digest a waste stream with 30% plastic. The TGER is fitted with a 60 kW generator and, at steady state, only about 10% of the energy produced is used parasitically to power the subsystems.

The residual output from the TGER system is a dry mix of ash and char, with the char to ash ratio being somewhat higher during initial start-up. As important as its energy production, TGER achieves an overall waste to volume reduction of 30:1, i.e., for every 30 cubic meters of garbage put in, one cubic meter of benign ash and char is produced, along with about two gallons per hour of grey water that can be distilled and used for drinking or field sanitation.

Residual waste from traditional coal power plants, particularly the fine fly ash collected from flue emissions, has been used in many applications including concrete fill, novel ceramics, and both carbon- and metal-matrix composites (Sear, 2001). The utility of a given ash or char residue for these applications typically depends on such characteristics as elemental and molecular composition, particle size, and particle shape. Ash is characterized as a very fine powder with no morphological characteristics related to the original material, whereas char is defined by its broad range of particle sizes and shapes, including morphological characteristics that are dependent upon the feedstock. An analysis of the morphology of the char and ash is critical because of the concern that nanoparticulates could have toxic properties that the same material would not have at meso- or micro-scales (Sear, 2001).

During field trials of the second generation TGER (TGER 2.0), samples of the residual ash and char were collected from the initial and final runs and these materials were subjected to elemental and morphological characterization. These results will be used determine the potential of these materials for reuse, with a goal of total recycling of all parts of the waste stream.

2. Materials and methods

2.1. Samples

The samples analyzed in this study were taken from the initial and final runs of the TGER 2.0 system during its testing at the Aberdeen Proving Ground, MD. Unlike typical studies which use a simple feedstock of wood chips or other biomass, the steady state feedstock input to TGER during these tests was a more realistic mixture of commercial food products and their packaging, plastic, cardboard and paper. Wet and liquid waste was fed to the bioreactor while cardboard (approximately 47 lbs/hr), polyethylene terephthalate plastic (approximately 6 lbs/hr), polystyrene plastic (approximately 5 lbs/hr) and the sludge from the bioreactor (approximately 3 lbs/hr) were fed to the gasifier. The dry residue produced from this processed waste was approximately 7 lbs/hr of mixed ash and char, all of which has been exposed to temperatures of approximately 900 °C. Portions of each sample, initial residue and final steady state residue, were milled for one minute in a small lab blender, primarily for ease of digestion for Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) and, for each sample, both the original and milled materials were analyzed. The samples tested represent random draws from the bulk of the residual char and ash material generated by the conversion of waste to energy, collected at initial start-up (2 h of TGER operation) and after achieving steady state (12 h of TGER operation).

2.2. Gross morphology

Gross morphology of the products was digitally photographed using a Nikon Coolpix P510 in macro mode, as well as on an Epson Perfection flatbed scanner. Using the scanner in this manner provides an image of a flat array of the sample with uniform lighting. The scanner software can also be used to magnify the scans, providing zoomed images without interference from the proximity of the camera lens. Areas of 25, 10 and 2.5 mm were scanned at 1200 dpi.

2.3. Inductively coupled plasma mass spectrometry

ICP-MS is a method in which the sample is digested into solution, ionized in a plasma, and introduced to a mass spectrometer for quantitative elemental analysis. The digestion of the samples is critical, as the only materials introduced into the instrument are those that have been successfully solvated. Early attempts with the TGER ash using general digestion procedures and unmilled samples resulted in incomplete digestion. A modified digestion protocol using a mixture of acids developed originally for fly ash digests and used here on the milled residue samples, proved to be very effective and was used for the results reported in this paper.

The digestion protocol was as follows: approximately 100 mg of each milled sample was digested in a mixture of 2 mL concentrated H_2SO_4, 2 mL concentrated H_3PO_4, 1.5 mL concentrated HNO_3, 1.5 mL concentrated HCl, and 1.5 mL concentrated HF. A Mars CEM microwave system was used to assist digestion, run at full power (400 W) to ramp to 250 °C over 35 min and hold at 250 °C for an additional 30 min.