A NEW METHOD FOR CONVERTING SEWAGE TO ENERGY USING SELF-SUSTAINING SMOULDERING

Tarek L. Rashwan
The University of Western Ontario, Canada

Jason I. Gerhard
The University of Western Ontario, Canada

Gavin P. Grant
Savron, Canada
The University of Western Ontario, Canada

EXECUTIVE SUMMARY

A major challenge in designing resilient infrastructure is to meet the needs of sustainable development (Kennedy & Corfee-Morlot, 2013). Sustainable development requires a high degree of energy efficiency. Municipal wastewater treatment plants (WWTPs), in particular, have the potential to be much more sustainable. In the U.S., 3 – 4% of the total energy consumed is dedicated to WWTPs and drinking water services, accounting for 30 – 40% of energy consumed by municipalities (U.S. EPA, 2014). In Canada, 25% of the $123 billion municipal deficit in 2006 was tied to water supply systems (i.e., drinking water, wastewater, and storm water) (Mirza, 2006). This problem becomes further complicated as much of North America's WWTP infrastructure approaches the end of its design life. An estimated $298 billion and $39 billion is required in the U.S. and Canada, respectively, to satisfactorily refurbish WWTP infrastructure (ASCE, 2013; Félio et al., 2012). Within WWTPs, around 50% of the operating and capital costs are dedicated to managing the solid by-product, biosolids, making it the most expensive system component (Khiari et al., 2004). In Canada, 90% of biosolids are either incinerated or land applied for agricultural purposes (Apedaile, 2001). These methods are expensive, requiring high energy inputs in various forms (e.g., fuel, labour, transportation) (Wang et al., 2008). Land application is also subject to limitations and uncertain risks due to the potential for introducing synthetic contaminants into the environment (Hale et al., 2001; U.S. EPA, 1995). In general, managing biosolids persists as a major energy intensive challenge within WWTPs and there is a strong need to provide novel solutions (Tyagi & Lo, 2013).

Self-sustaining smouldering combustion of organic wastes was originally developed as a chemical waste management and soil-clean up technology (Pironi et al., 2011; Scholes et al., 2015; Switzer et al., 2009). Smouldering is a flameless form of combustion for solid and liquid fuels, where a common example is glowing red charcoal in a traditional barbeque (Ohlemiller, 1985). The fuel (e.g. oil sludge) is mixed with sand to form a fixed-bed; this increases the surface area for reaction, provides porosity for the oxidant (air), and efficiently transfers, stores, and recycles the released reaction energy (Switzer et al., 2009). The smouldering reaction typically reaches temperatures between 500-800°C for many minutes in one location resulting in upwards of 99% conversion of organic waste to heat (Pironi et al., 2011). Smouldering in this configuration is unique as it supports an extremely energy efficient, self-sustaining reaction; therefore, following ignition, no external energy is required to sustain the reaction indefinitely. As a result, the process can smoulder fuels containing little energy or significant water contents that would otherwise not burn (e.g., via incineration) (Switzer et al., 2009; Yermán et al., 2015).

Proof-of-concept experiments demonstrated for the first time that biosolids, obtained from Greenway Pollution Control Centre (London, ON) could be successfully destroyed via self-sustained smouldering. Thirty experiments in 40 cm tall, 15 cm diameter fixed-bed columns mapped the parameter space of self-sustained smouldering as a function of sand dilution, biosolids water content, and injected air flow rate. The results demonstrate that a self-sustaining reaction was achieved using biosolids with water contents as high as 80% (1.6 MJ/kg, effective calorific value). With little input of energy, the biosolids were converted to heat, steam, and emissions dominated by carbon dioxide. These

results suggest that smouldering presents strong potential as a cost and energy effective waste management alternative for WWTP biosolids, achieving on-site destruction with minimal energy input and limited preliminary processing (Rashwan et al., 2016). This underscores the beneficial application of smouldering as a novel waste management technique that may be useful in designing resilient infrastructure.

REFERENCES

Apedaile, E. (2001). A perspective on biosolids management. *The Canadian Journal of Infectious Diseases and Medical Microbiology, 12*(4), 202.

ASCE. (2013). Wastewater *2013 Report Card for America's Infrastructure*. Reston: American Society of Civil Engineers.

Félio, G., Ferreira, B., McNally, C., Robertshaw, R., Andres, R., Siu, K., Buda, M., Thompson, A., Lounis, Z., & CIRC. (2012). Municipal Roads and Water Systems *The Canadian Infrastructure Report Card Vol. 1* (Vol. 1). Ottawa.

Hale, R. C., La Guardia, M. J., Harvey, E. P., Gaylor, M. O., Mainor, T. M., & Duff, W. H. (2001). Flame retardants: Persistent pollutants in land-applied sludges. *Nature, 412*(6843), 140-141.

Kennedy, C., & Corfee-Morlot, J. (2013). Past performance and future needs for low carbon climate resilient infrastructure–An investment perspective. *Energy Policy, 59*, 773-783.

Khiari, B., Marias, F., Zagrouba, F., & Vaxelaire, J. (2004). Analytical study of the pyrolysis process in a wastewater treatment pilot station. *Desalination, 167*, 39-47.

Mirza, S. (2006). Durability and sustainability of infrastructure-a state-of-the-art report. *Canadian Journal of Civil Engineering, 33*(6), 639-649.

Ohlemiller, T. J. (1985). Modeling of smoldering combustion propagation. *Progress in energy and combustion science, 11*(4), 277-310.

Pironi, P., Switzer, C., Gerhard, J. I., Rein, G., & Torero, J. L. (2011). Self-sustaining smoldering combustion for NAPL remediation: laboratory evaluation of process sensitivity to key parameters. *Environmental Science & Technology, 45*(7), 2980-2986.

Rashwan, T. L., Gerhard, J. I., & Grant, G. P. (2016). Application of self-sustaining smouldering combustion for the destruction of wastewater biosolids. *Waste Management, 50*, 201-212.

Scholes, G. C., Gerhard, J. I., Grant, G. P., Major, D. W., Vidumsky, J. E., Switzer, C., & Torero, J. L. (2015). Smoldering Remediation of Coal-Tar-Contaminated Soil: Pilot Field Tests of STAR. *Environmental Science & Technology, 49*(24), 14334-14342.

Switzer, C., Pironi, P., Gerhard, J., Rein, G., & Torero, J. (2009). Self-sustaining smoldering combustion: a novel remediation process for non-aqueous-phase liquids in porous media. *Environmental Science & Technology, 43*(15), 5871-5877.

Tyagi, V. K., & Lo, S.-L. (2013). Sludge: A waste or renewable source for energy and resources recovery? *Renewable and Sustainable Energy Reviews, 25*, 708-728.

U.S. EPA. (1995). *Part 503 Implementation Guidance* (Office of Water, Trans.). Washington: U.S. Environmental Protection Agency.

U.S. EPA. (2014). Energy Effeciency for Water and Wastewater Facilities. *Water: Sustainable Infrastructure.* Retrieved February 16, 2015, from http://water.epa.gov/infrastructure/sustain/sustainable_infrastructure.cfm

Wang, H., Brown, S. L., Magesan, G. N., Slade, A. H., Quintern, M., Clinton, P. W., & Payn, T. W. (2008). Technological options for the management of biosolids. *Environmental Science and Pollution Research-International*, *15*(4), 308-317.

Yermán, L., Hadden, R. M., Carrascal, J., Fabris, I., Cormier, D., Torero, J. L., Gerhard, J. I., Krajcovic, M., Pironi, P., & Cheng, Y.-L. (2015). Smouldering combustion as a treatment technology for faeces: Exploring the parameter space. *Fuel*, *147*, 108-116.