Microwave Drying of Automotive Industry Paint Sludge

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Abstract: The moisture content of process sludges generated by industries is an important problem affecting the cost and convenience of sludge management. Sludge can be dried to decrease its volume and reduce most of the moisture. This research analyzes the microwave drying process of water-based paint sludge from the automotive industry by investigating the influence of dielectric constant, sludge form (raw or ground), drying method (microwave and conventional), drying period, and air curing, and by conducting numerical modeling. The drying period of sewage sludge is also analyzed for comparison. The moisture losses range between 8 and 12% and between 26 and 31% for 5 and 10 min microwave drying periods, respectively. The moisture losses obtained with conventional heating range between 0.2 and 1.2% and between 0.7 and 2.9% for 5 and 10 min drying, respectively. Air curing of the samples following microwave drying results in a 3% increase in the moisture losses. Numerical modeling results show that the dielectric characteristics of the paint sludge might change during the drying process inside the oven and different chemical compositions of the sludges might lead to temperature changes during the drying process. By modeling the microwave oven, it is possible to determine the regions that can dissipate more heat without measuring, which is confirmed with the dissipated power density maps and electric field distribution obtained. **DOI: 10.1061/(ASCE)HZ.2153-5515.0000407.**

Author keywords: Dielectric constant; Numerical modeling; Moisture loss; Electric field distribution.

Introduction

Sludge is a semisolid residual left from industrial or wastewater treatment processes. It typically contains major quantities of interstitial water, moisture, between its solid particles. The amount of this moisture is a problem affecting the cost and convenience of sludge management.

Painting processes in the automotive industry are the major source of the waste generated. Paint sludge is reported to be the major waste fraction of this process, and is classified as EU hazardous waste code 080113* (EU 2000). Bearing a high organic carbon content, paint sludge is mostly incinerated as hazardous waste or combusted in cement kilns as refuse-derived fuel (RDF) (Salihoglu and Salihoglu 2016). However, the high moisture content of the paint sludge, more than 60%, makes the acceptability of this material by cement kilns difficult. Drying can be applied to reduce most of the moisture content of the paint sludge and facilitate its storage, transportation, and combustion.

Thermal energy is widely used in sludge management applications such as incineration, pyrolysis, quasi-pyrolysis, gasification, and coincineration at cement plants. Generally, a drying step is necessary before the use of the sludge as RDF at cement kilns (Kacprzak et al. 2017). The high moisture content of the sludge complicates the combustion process within the cement kilns and increases the cement production costs. Werther and Ogada (1999) reported that the maximal feed rate of sludge should be kept at 5% of the clinker production capacity of the cement kiln because of the possibility of incomplete combustion of sludge particles and higher CO emissions generated.

Drying is the act of adding energy to the system to evaporate the water inside and lower the moisture content. Further thermal treatment of the sludge would be more feasible after a drying step (Cieslik et al. 2015; Werle and Wilk 2010). As an alternative technology for sludge drying, the use of microwave (MW) irradiation has attracted growing interest because it brings advantages such as rapid heating and drying and destruction of the material structure, resulting in the release of bound water, which facilitates the dewatering process (Yu et al. 2009). High-frequency microwave irradiation interacts with the dipolar water molecules inside the sludge, and a rapid heating followed by drying of the material occurs.

Collins et al. (1991) investigated removal of water from sludges through the use of microwaves at bench scale, and reported that sample location on the microwave turntable, the container empty space volume, and the heating surface area were the factors affecting the process. They also reported that below a certain critical initial water mass, microwave heating efficiency decreased rapidly. Collins et al. (1991) conducted experiments involving both organic and inorganic sludges and found that water removal was independent of the nature of sludge solids. Chen et al. (2014) investigated the influence of microwave power levels on the drying of sewage sludge and reported a significant correlation. They also showed an increase in the calorific value of the sludge sample after the application of microwave irradiation (Chen et al. 2014). Bennamoun et al. (2015) studied the effect of mass and microwave powers on the drying characteristics and developed a mathematical model for moisture diffusion. Jinping et al. (2015) obtained drying curves under different thicknesses and diameters of the sludge.

Microwave radiation is mostly used by the food industry for pasteurization and sterilization. Research has shown that it can be adopted for sludge pasteurization and drying (Tyagi and Lo 2013).

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Note. This manuscript was submitted on October 28, 2017; approved on January 30, 2018; published online on May 25, 2018. Discussion period open until October 25, 2018; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Hazardous, Toxic, and Radioactive Waste***, © ASCE, ISSN 2153-5493.