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Characterization of ash deposits from municipal solid waste (MSW) incineration plants

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Abstract

In this work, chemical compositions and micro morphologies and structures of ash deposits from two municipal solid waste-to-energy (WtE) plants in Norway were analyzed and characterized. The ash deposits were sampled from different locations in the combustion chamber. The samples were analyzed by a combination of a scanning electron microscopy equipped with energy dispersive X-ray spectroscopy (SEM-EDX) and X-ray fluorescence (XRF). The samples collected from locations close to the grate contain high concentrations of Ca and Si. Concentrations of K, Na, Cl and S in the deposits sampled from the top of the combustion chamber are significantly high. A layered structure can be seen from the deposit samples. The inner layer closer to or directly in contact with a heat transfer tube surface can be considered as primary deposits that have high concentrations of Cl, S, K and Na. The primary deposit layer has dense and compact structure due to the sintering and melting of deposited ash particles and grains. Together with XRF analysis, the SEM-EDX analysis revealed that the primary deposits are probably formed due to deposits of fused sulfates and chlorides on the heat transfer tube surfaces. The outer layer of the ash deposits has more loose structure formed due to agglomeration of smaller size grains. SEM-EDX and XRF analyses showed that the Ca, Si, Al and S are dominant elements in these large grains, indicating existence of calcium sulfates, silicates and calcium and silicon oxides.

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Keywords: Waste-to-Energy, Municipal solid waste, ash, deposits

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1. Introduction

Incineration with energy recovery is currently the most important and efficient way to dispose and manage Municipal Solid Waste (MSW) worldwide [1]. The volume and amount of MSW can be significantly reduced through incineration. It preserves landfilling space and limits the negative effects of MSW to environmental and water systems. The MSW incineration is often combined with heat and power production and material recycling, which maximizes the valorization of MSW. However, MSW is a mixture of inhomogeneous materials with high ash content and complex chemical compositions. MSW usually contains high concentrations of chlorine, sulfur and alkali metals, and minor concentrations of heavy metals like lead and zinc. During transportation and storage, MSW is often contaminated by soil, sand and stone, which enhances the Si content in the MSW. During incineration, a large fraction of the inorganic elements in the MSW will volatilize and transform through complex chemical reactions. Part of the MSW, its combustion residues and generated ashes will be entrained by inlet air through the fuel bed, into finally the flue gas. These volatiles and entrained fine fuel/ash particles in the flue gas can lead to formation of deposits on heat transfer surfaces [2]. With accumulation and sintering of the ash deposits, the heat transfer can be significantly hampered, decreasing the energy conversion efficiency of the WtE plant. Additionally, certain elements (mainly Cl and S) and chemicals in the ash deposits attack the heat transfer tube, leading to corrosion and thinning of the tubes. This requires costly cleaning and maintenance for the heat transfer tube surfaces and therefore reduce the economic viability of WtE. It is necessary and important to perform detailed characterization and analyses of deposits collected from the MSW incineration plants in order to understand ash deposition formation processes, to be able to propose effective mitigation measures.

2. Materials and Methods

2.1. Sample

Four ash deposit samples in total were collected from two Waste-to-Energy (WtE) plants in Norway. The first two ash deposit samples were collected from Heimdal WtE plant operated by Statkraft Varme AS. The other two ash deposit samples were collected from Haraldrud WtE plant operated by EGE Waste to Energy Agency in Oslo. All ash deposits were sampled directly from the heat transfer tube surfaces during planned shutdown and maintenance periods. In both WtE plant, the combustion system is based on a moving inclined grate with two-stage air injection. The primary air is preheated and distributed throughout the grate in several separately controlled zones. The secondary air is injected from top of the combustion chamber. The bottom ash is discharged to a chain conveyor at the far end of the grate. The four ash deposit samples were collected from vertical surface locations from close to the grate to the top of the right side wall of the primary combustion chamber. From the Heimdal WtE plant, the ash deposit sample #1 was collected at a position 2 meters above the grate. It means that this sample was exposed to a higher temperature and probably direct flame contact as well. The ash deposit sample #2 was collected from a position 10 meters above the grate, which is at the top of the combustion chamber. This is the zone where the flue gas turns and flows into the superheater section. In the Haraldrud WtE plant, the ash deposit sample #3 was also collected from a position about 2 meters above the grate. The ash deposit sample #4 was collected from a position below the flue gas entrance to the superheater section, which is about 8 meters above the grate. The four collected ash deposit samples were photographed and labelled right after collection. In order to analyze the deposition formation mechanisms, two sub-samples were obtained from the inner and outer layers of the original ash deposit samples. A similar sampling method and procedure can be found in our previous work [2, 3]. Therefore, in total eight samples were analyzed.

2.2. Sample analysis

The two sub-samples were carefully cut from the inner and outer layer of an original ash deposit sample respectively, in order to retain their initial rather dense structure and compact surface. Each sub-sample was divided into two parts for further chemical composition, microstructure and chemistry analyses. A portion of the sample was crushed into a fine powder and analyzed by an X-ray fluorescence (XRF) analyser (Bruker, S8 Tiger) for quantifying concentrations of elements in a sample. The XRF analyses results are presented as oxides. The other part of the sample