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Self-heating of dried industrial wastewater sludge: Lab-scale investigation of supporting conditions

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ABSTRACT

We studied the reactivity of dried sludge produced by treatment of wastewater, mainly from tanneries. The solids transformations have been first characterized with thermal analysis (TGA and DSC) proving that exothermic transformation takes place at fairly low temperature, before the total organic combustion that occurs in air above 400 °C. The onset of low temperature reactions depends on the heating rate and it can be below 100 °C at very small heating rate.

Then, we reproducibly determined the conditions to trigger dried sludge self-heating at the laboratory scale, on samples in the 0.2–0.3 kg size. Thermal insulation, some aeration and addition of water are key factors. Mastering the self-heating at this scale allows more detailed investigations as well as manipulation of conditions, to understand its nature, course and remediation. Here we report proves and discussions on the role of air, water, particle size, porosity and biological activity, as well as proving that also dried sludge from similar sources lead to self-heating.

Tests demonstrate that air and water are simultaneously required for significant self-heating to occur. They act in diverging directions, both triggering the onset of the reactions and damping the temperature rise, by supporting heat loss. The higher the O_2 concentration, the higher the solids heating rate. More added water prolongs the exothermic phase. Further additions of water can reactivate the material. Water emphasizes the exothermic processes, but it is not sufficient to start it in an air-free atmosphere. The initial solid moisture concentration (between 8% and 15%) affects the onset of self-heating as intuitive. The sludge particles size strongly determines the strength and extent of the heat release, indicating that surface reactions are taking place. In pelletized particles, limitations to water and air permeability mitigates the reaction course.

1. Introduction

The occurrence of spontaneous self-heating of organic solid wastes is well known (Hogland et al., 2009). Dried wastewater treatment sludge is particularly hazardous and fire is a concern in the management of both drying plants and storages. In a previous work (Zerlottin et al., 2013) we reviewed cases reported in the literature and described its occurrence in our specific application, where large volumes of sludge are routinely dried, starting from a mostly industrial wastewater treatment. We investigated sludge self-heating at a large, industrial scale, based on big-bags of approx. 1 m^3 capacity. Two distinct behaviors were reported, confirming previous reports on sludge (Poffet et al., 2008) as wells as generic solid waste (Moqbel et al., 2010). Either the sludge mass increases its temperature up to a maximum of approx. 90 °C before cooling or an unbounded temperature rise leads to self-combustion. The second circumstance is particularly alarming but we clearly proved (Zerlottin et al., 2013) that it occurs only when the sludge has undergone an uncontrolled drying history. At any rate, some heating is always observed. It can be weak enough to fade out in a few hours, depending on the heat exchange rate of the sludge mass and its aeration.

We devised a strategy to prevent undesired overheating of the sludge (Zerlottin et al., 2013), but a better understanding of the conditions that enhance or limit the process is sought, preliminary to the identification of the chemical, physical and possibly biological mechanisms that determine the material heating. For this purpose, flexibility in experimentation is required, given that large scale tests do not allow all the modifications of the operative conditions and material properties desired.

Bringing a process observed at large scale down to a laboratory scale is not straightforward. Loss of sensibility and representativeness when dealing with heterogeneous materials are common concerns, particularly when analytical methods are used. Several techniques have been used in the past to characterize the thermal

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