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On the understanding and control of the spontaneous heating of dried tannery wastewater sludge

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ABSTRACT

We studied the spontaneous heating of dried sludge produced by treating wastewater mainly originating from tanneries. Heating up to burning has been observed in the presence of air and moisture, starting at ambient temperature. To understand and prevent the process we combined chemical and morphological analyses (ESEM) with thermal activity monitoring in insulated vessels. Selective additions of chemicals, either to amplify or depress the reactivity, have been used to investigate and identify both the chemical mechanism causing the sludge self-heating, and a prevention or a mitigation strategy. FeS additions accelerate the onset of reactivity, while S sustains it over time. On the contrary, $Ca(OH)_2$, Na_2CO_3, $NaHCO_3$, $FeCl_2$, EDTA, NaClO can limit, up to completely preventing, the exothermic activity. All the experimental evidences show that the reactions supporting the dried sludge self-heating involve the Fe/S/O system. The total suppression of the reactivity requires amounts of additives that are industrially incompatible with waste reduction and economics. The best prevention requires reduction or removal of S and Fe from the dried solid matrix.

1. Introduction

After the occurrence of unusual temperature in a dedicated landfill for exclusive disposal of dried sludge from tannery wastewater treatment, an extensive investigation to evaluate the hazard, the self-heating causes and the prevention strategies has been carried out. We already reported (Zerlottin et al., 2013) a large scale experimental study, based on 1 m^3 big-bags, where we deterministically reproduced the self-heating processes, observing two distinct behaviors, depending on the drying operations. 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, without any flame. The second case is extremely critical for safety and pollution (Nammari et al., 2004), but we clearly proved that it occurs only after an uncontrolled drying operation. Yet, some heating is always observed, but in most cases it is weak enough to independently extinguish in a few days, depending on the heat exchange rate of the sludge mass and its aeration. The sequence of a faint heating that may trigger total combustion has been reported by many authors, on wastewater sludge (Poffet et al., 2008), as wells as other solid wastes (Moqbel et al., 2010; Hogland and Marques, 2007, Hogland et al., 2009; Buggeln and Rynk, 2002; Shimizu et al., 2009), and solid fuels, typically coal (Carras and Young, 2004; Nelson and Chen, 2007; Ribeiro et al., 2010; Phillips et al., 2011; Day, 2000).

We devised a procedure (Della Zassa et al., 2013) to reproduce the initial self-heating process at the laboratory scale, to manipulate either the solids or its environment, aiming at investigating the mechanism. So far we reported the enhancing (or damping) effect of aeration, moisture content (also by addition of water) particle size, bed and particle porosity and biological activity (Della Zassa et al., 2013). Apparently, fermentation is rather marginal in the heating process (Della Zassa et al., 2013; Li et al., 2006); a chemical route is clearly prevailing, as confirmed by spontaneous heating and combustion of solids that have little or no putrescible components, such as coals (Carras and Young, 2004; Nelson and Chen, 2007; Ribeiro et al., 2010; Phillips et al., 2011; Day, 2000), refuse derived fuel (RDF) (Yasuhara et al., 2010; Fu et al., 2005; Li et al., 2008) and refuse plastic/paper fuel (RPF) (Li et al., 2009). In most of these cases, the inorganic components are deemed responsible of the self-heating potential (Sujanti and Zhang, 1999), in addition to moisture that is always a key factor.

Here we aim at better understanding the chemical mechanism that supports the self-heating process, beyond simple thermal monitoring, to include chemical and morphological analysis of the solids, mainly performed by ESEM–EDS technique, as well as discussing the effect of chemical additives expected to inhibit or delay the self-heating process. Finally, the process understanding's goal is the identification of prevention policies, including

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