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Modelling of PCDD/F release from MSW bio-drying

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Abstract

In the present work, an experimentation was carried out to study the behaviour of PCDD/F during the process of municipal solid waste (MSW) bio-drying. This process belongs to the biological mechanical treatment (BMT) options and is aimed to the dewatering of MSW thanks to the biological exothermal reactions (thermal drying, on the contrary, needs an external heat source as methane). The result is a decrease of waste weight and an increase of lower heating value (as the energy content refers to a lower amount of waste). Of course, the overall energy availability does not increase, but the characteristics of bio-drying are interesting as a way for refuse derived fuel generation: glass, metals and inert removals are easier after bio-drying. The literature of the sector shows only few data on PCDD/F emission to air from BMT. Anyway, in the present work an original theory has been put forward in order to explain the enrichment of PCDD/F in the air exiting the biological processes. The role of the initial PCDD/F concentration in the ambient air entering the plant is obviously taken into account. The results of the developed experimentation and the following elaborations point out that PCDD/F could be freed from the volatile solids consumed during the process. The different amount of PCDD/F in the waste and the different consumption of volatile solids depending on the biological process can explain the different PCDD/F emission factors available in the literature.

Keywords: Bio-drying; Dioxin; Emissions; Modelling; Municipal solid waste

1. Introduction

The discussions on PCDD/F emissions from municipal solid waste (MSW) treatments are usually referred to incineration. Anyway, today it is known that this is not the only MSW treatment process that may cause PCDD/F emission into the atmosphere. Biogas from sanitary landfill can be responsible of a PCDD/F release to the atmosphere even if no combustion is performed. Process air exiting a mechanical biological treatment plant can have a concentration of PCDD/F higher than the one of the air entering it (Rada et al., 2005a). The present work wants to give an explanation to this last aspect of PCDD/F role and is inspired from some considerations. First of all, it is known that untreated MSW has very changeable PCDD/F concentrations: for example in the UK they have found an average PCDD/F concentration of about 6.3 ng I-TEQ kg^{-1} (Eduljee and Dyke, 1997), in Germany about 73 ng I-TEQ kg^{-1} (Landesumweltamt Nordrhein-Westfalen, 1997), in Italy about 20 ng I-TEQ kg^{-1} (Franzinelli et al., 2004a,b). Since residual MSW is heterogeneous, micro-pollutants like PCDD/F are not immobilized in the waste matrix and they may show mobility; so it is reasonable to hypothesize that a fraction of the PCDD/F contained in the waste can have sufficient mobility to be stripped, for example, by an air flow blown into the waste. This consideration is confirmed if we think that in the biogas emitted from a landfill (before its combustion) PCDD/F concentrations as 5–117 pg I-TEQ Nm^{-3} (Cernuschi, 2001) have been found. Obviously, the gas flow coming out from the landfill body is very low; on the contrary, if we consider for example both the MSW bio-drying process and the MSW bio-stabilization process, a high specific air flow-rate is blown into the waste, typically 5–10 Nm^3 kg^{-1}: so it is important to evaluate the PCDD/F mobility to decide which kind of gas treatment

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unit has to be installed in order to minimize the health risk. Bio-drying belongs to the biological mechanical treatment options and is aimed to the dewatering of MSW thanks to the biological exothermal reactions (thermal drying, on the contrary, needs an external heat source as methane, in order to increase the lower heating value of the treated material).

The present work starts first of all from the literature of the sector: data collected in Europe about BMT plants confirm that PCDD/F concentration in exhaust air is not negligible (Rada et al., 2005a). A recent elaboration of the literature data allowed to propose emission factors useful for life cycle analysis studies (Rada et al., 2005b,c,d), ranging from 1 to 60 pg I-TEQ kg^{-1}, depending on the waste characteristics, the biological process and the exaust air treatment. Studying in details the bio-drying process it can be seen that it is characterised by a biodegradable volatile solid consumption and a water evaporation. The present research has the aim of verifying if there is a relationship between the PCDD/F in the process air and the PCDD/F present in the organic fraction (OF) before the treatment. Indeed, referring to the same PCDD/F content in the MSW and to the same air treatment systems (presence of absence of best available technologies), the emission factors elaborated in Rada et al. (2006a) increase with the volatile solid consumption and then it is reasonable to suppose that PCDD/F could be freed from the volatile solids (VS) of the organic fraction.

2. Materials and methods

In order to develop MSW bio-drying runs, two bioreactors have been implemented in the University of Trento: a 0.7 m^3 pilot plant reactor without leachate collection and a 1 m^3 pilot plant reactor with leachate collection (Franzinelli et al., 2004a,b; Rada et al., 2005b, 2006b). The addition of devices for leachate collection allowed a better characterization of the process.

The pilot scale biological reactor without leachate collection was used for a research concerning only the release to air of PCCD/F from bio-drying treatment. The reactors are shown in Fig. 1 and were equipped with aeration devices, temperature probes and electronic balance. A software allowed the management of the system in order to simulate a MSW bio-drying process. The pilot plant was provided with a PCDD/F sampling unit. This was equipped with two “cold traps” and one“dry trap”. Exhaust air came out from the biological reactor and flowed into two glass condensers (“cold traps”) connected in series and cooled by a refrigeration unit: the exhaust air flow condensed in the cold trap and so it was possible to collect PCDD/F present in air both as aerosol and in gas phase. After the cold unit, the exhaust air went through a polyurethane foam trap, PUF (or “dry trap”), installed in order to capture non-condensable PCDD/F. Before using the sampling unit for the trials, this was tested in order to verify if the efficiency in capturing PCDD/F was higher than 95%, as prescribed by UNI-EN 1948 (UNI, 1999a,b,c): results confirmed that the PCDD/F sampling unit had an efficiency higher than 99%.

Fig. 1. Biological reactor without leachate collection (left) and with leachate collection (right).

The biological reactor with leachate collection (Fig. 1, right), is an adiabatic box that measures $1000 \times 1000 \times 1000$ mm having a useful volume of around 1 m^3. The walls are constituted by a double plate in steel, with, inside, a 40 mm panel for guaranteeing the thermal isolation. The MSW is placed in the reactor opening the cover set on the upper side of the biological reactor, while at the end of the run it is discharged laterally. The control system is the same of the first reactor.

The installation of a PUF at the aspiration of the compressor is necessary for introducing in the biological reactor dioxin-free air. In this way it is possible to calculate how much the bio-drying process is responsible of the presence of dioxin in the process air discharged from the bioreactor. With the first reactor (Fig. 1, left) four trials were performed in order to estimate the PCDD/F concentration in exhaust raw process air from bio-drying, to compare it with PCDD/F ambient level and to assess the emission factor from the process without air treatment.

The first trial was performed with the reactor empty, in order to verify possible PCDD/F releases from the materials of the system. Exhaust air and ambient air were sampled by a polyurethane foam installed before the compressor and at the reactor outlet. The second and the third trials were managed using MSW collected in Trento town. The fourth trial was divided into three steps to evaluate if PCDD/F concentration in raw exhaust air can change during the process. Ambient air samplings were performed too by a high volume sample activated in the same period of the run. Anyway, if we want to evaluate the environmental impact of PCDD/F emission we have to consider PCDD/F emission factor and not only PCDD/F concentration. Thus, flowrate was measured in order to assess the emission factors for each trial.

With the second reactor, a trial with a more detailed emissions characterisation was performed. Waste entering the system, leachate and air were characterised in order to study the behaviour of PCDD/F during the process.

A representative sampling of organic fraction MSW (OFMSW) locally generated in Trento was performed.