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What is the acceptable margin of error for the oxygen uptake method in evaluating the reactivity of organic waste?

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ABSTRACT

The acceptable margin of error for the organic waste reactivity measured by the oxygen uptake method was assessed. Oxygen uptake was determined by the Dynamic Respiration Index (DRI) (mgO_2/kgVS h). The composed uncertainty (*uC*) of the experimental set up used for the DRI test was evaluated and the uncertainty (*u*) of all the components of the apparatus was evaluated. A procedure for calculating the *uC* of the apparatus is proposed. The components affecting the *uC* of the DRI to a more significant extent were the one of the oxygen mass rate and the *u* of the amount of VS in the sample analyzed. For a confidence level of 99.73%, the extended *uC* (*UC*) interval for a DRI = 1024 mgO_2/kgVS h was ±440 mgO_2/kgVS h, whereas for a DRI = 3489 mgO_2/kgVS h, the *UC* interval was ±1288 mgO_2/kgVS h. When oxygen consumption and VS content become lower than 600 mgO_2/h and 0.9 kg, respectively, the *UC* interval is similar to the measured DRI.

1. Introduction

The EU policy in waste management strongly supports reuse and recycling (WFD, 2008/98/EC) and imposes a mandatory stepwise directive for reducing the amount and reactivity of waste disposed of in landfills. For this reason, since 1999 the Landfill Directive (99/31/EC) imposes limitations both on the energetic content and on the amount of the biodegradable fraction of waste going directly to landfills. In particular, landfilling of biodegradable waste causes the production of a significant amount of greenhouse gas emissions as well as the release of polluting substances into the leachate (Di Maria et al., 2013a, b), creating a serious environmental risk.

One strategy for achieving these goals is source-separated collection, which diverts recyclables such as plastic, paper, metal and the organic fraction (OF) of municipal solid waste (MSW) from landfills. Recyclable materials can then be used to substitute raw materials, and the of can be processed by biological treatment to produce renewable energy and/or organic fertilizer (Frike et al., 2005; Nguyen et al., 2007).

Even if high source segregation rates are achieved, a large amount of residual MSW (RMSW) will still be generated (Glaivc and Lukman, 2007; Matete and Trois, 2008), including a large fraction of residual of (Di Maria, 2012). Incineration is a suitable solution for RMSW treatment before landfilling, leading to material stabilization, mass reduction and energy recovery. However, treatment costs for incineration depend greatly on scale factors and incineration has a low social acceptance in many EU countries.

Another possible solution extensively used in many EU areas for managing RMSW in accordance with the EU Directive is Mechanical Biological pre-Treatment (MBT). This method consists in converting RMSW via mechanical and biological processes mainly aimed at stabilizing the biological degradable components (Di Maria 2012¸ Wiemer and Kern, 1995). For this reason many EU States have adopted specific rules for establishing the features of RMSW acceptable for landfilling. In particular the biological reactivity of the landfill fraction (LF) has to be lower than given values evaluated by standardized tests. These tests can be anaerobic, such as GS and GB (Binner and Zach, 1999; Binner et al., 1999) or aerobic such as SOUR, AT and the respiration index (Wagland et al., 2009). Anaerobic tests evaluate the volume of gas produced by a given amount of waste sample under given conditions related to the amount of solids, on dry matter basis (DM). These tests usually require more than 21 days and process a rather small amount of waste (*i.e.* ≤2 kgDM). Aerobic tests usually last from 4 to 7 days and the biological reactivity is evaluated by measuring the amount of oxygen consumed and/or carbon dioxide produced both with respect to total solids (TS) (%w/w on wet matter basis) and to the volatile solids (VS) (%TS) concentration. Among the aerobic tests, the Dynamic Respiration Index (DRI) (mgO_2/kgVS h) (Scaglia et al., 2000) shows particularly interesting features for evaluating

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the biological reactivity of the LF. Short test duration, usually about 4 days, avoidance of inhibiting conditions and the amount of the sample processed, generally more than 5 kg wet matter, make DRI suitable for characterizing waste prior landfill disposal (Scaglia et al., 2010).

However, there is still a fundamental question regarding all of the above-mentioned tests and in particular regarding the DRI. The question deals with evaluation of the uncertainty of the values measured by this method. Once all the possible errors occurring during a measurement have been defined and eventually corrected, the uncertainty is the evaluation of how well the values measured represent the real ones (UNI CEI ENV, 2000), that is, the acceptable margin of error. Considering the relevance of the DRI in waste management, the stochastics affecting the sampling procedure and the complexity of the apparatus used to evaluate it, this issue is of prominent importance. In fact, some authors have proposed evaluating the DRI precision (Scaglia et al., 2011a) by determining the repeatability and the reproducibility (Scaglia et al., 2011b). These concepts are different from that of the uncertainty. Repeatability allows the maximum acceptable difference between two measurements made consecutively on the same material to be determined, in the same laboratory using the same apparatus and the same operators. Reproducibility allows the same acceptable difference to be determined when the test on the same material is performed by varying one or more of these aspects. However, neither repeatability nor reproducibility allows the interval of values in which the true measured value is located to be determined. Considering the lack of information available on this topic, the present study was conducted to develop a procedure for evaluating the uncertainty of the DRI, according to UNI CEI ENV (2000), using an experimental apparatus respecting the UNI/TS 11184 (2006) standards.

2. Materials and methods

2.1. Sampling and characterization

Eight large samples of about one tonne of LF with different lengths of time of pre-treatment were withdrawn from a full-scale MBT. By the quartering procedure about 200 kg of LF were selected and screened with a 30 mm sieve. The undersize was divided into 20 samples of about 5 kg each and the composition in terms of biodegradable, biologically inert, and fines (<20 mm) was manually determined. After composition analysis the samples were analyzed for moisture content (MC) and VS. MC (%w/w) and consequently TS (%w/w) were determined after drying at 105 °C for 24 h. VS (%TS) were determined by burning the TS (%w/w) at 550 °C for 24 h. The remaining fraction was mixed and used for DRI determination.

2.2. DRI experimental set up

The experimental apparatus used for the DRI evaluation is shown in Fig. 1 and was built according to UNI/TS 11184 (2006).

The LF sample was put in a 30-l cylindrical basket with a perforated bottom until 2 cm from the cover. The basket was then put inside an aerobic reactor and the top was closed in order to avoid uncontrolled gas leakage. The process air from the compressor first passes through a flow meter and regulator (specification see Table 1) before entering the reactor bottom. Waste air is collected at the top of the reactor. In this way all of the air entering the reactor is forced to pass through the LF inside the basket, enhancing the aerobic biodegradation process. The exhaust air in the reactor top is piped into a condensing/scrubbing device, where the air is gurgle through a given amount of cooled water to remove humidity and other impurities. After the scrubber, the exhaust air enters a chamber in which there is an oxygen sensor (spec. see Table 1) and is then definitively discharged. To avoid the risk of anaerobic conditions, the minimum oxygen concentration of the exhaust air is set at ⩾14 (%v/v) (UNI/TS 11184, 2006). During the test if the oxygen concentration goes under this limit, the inlet air rate is increased by the flow meter and regulator until the concentration is again ⩾14 (%v/v).

The entire process is controlled and monitored by a program specifically developed for this and installed on a PC. The program calculates the oxygen uptake every minute as the difference between the mass rate of oxygen entering (MO_{2in}) (mgO_2/min) and exiting (MO_{2out}) (mgO_2/min) the reactor and then the hourly DRI (DRI_h) (Eq. (1)) oxygen uptake as the difference of the values achived by the DRIion index (DRI)). Flow rate is increased of a given amount tor. The DRI (Eq. (2)) is then calculated as the maximum value of the average hourly DRI determined on a 24 h basis.

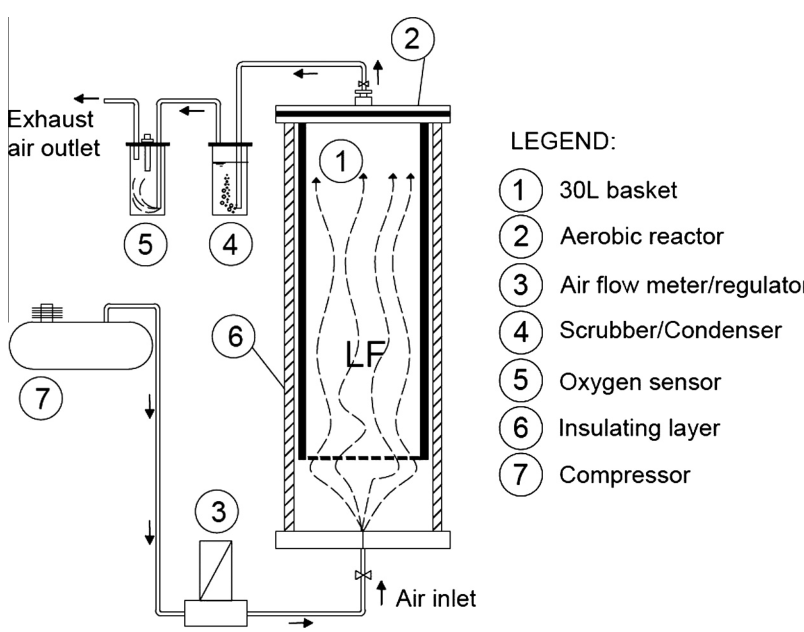

Fig. 1. Scheme of the experimental apparatus.