Atmospheric Environment 94 (2014) 117–125

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Technical note

Novel application of a combustion chamber for experimental assessment of biomass burning emission

Ilaria Lusini [a,b], E. Pallozzi [a], P. Corona [c], P. Ciccioli [d], C. Calfapietra [a,e,*]

[a] Institute of Agro-Environmental & Forest Biology (IBAF), National Research Council (CNR), Viale Marconi 2, 05010 Porano, Terni, Italy
[b] Department for Innovation in Biological, Agro-food and Forest Systems, University of Tuscia, Via San Camillo de Lellis snc, Viterbo, Italy
[c] Consiglio per la ricerca e la sperimentazione in agricoltura, Forestry Research Centre (CRA-SEL), Viale S. Margherita 80, Arezzo, Italy
[d] Institute of Chemical Methodologies (IMC), National Research Council (CNR), Via Salaria km 29,600, Monterotondo Scalo, Rome, Italy
[e] Czechglobe, Global Change Research Centre, Academy of Sciences of the Czech Republic, v.v.i., Bělidla 986/4a, 603 00 Brno, Czech Republic

HIGHLIGHTS

- We describe a new combustion chamber for studying emission from biomass burning.
- We examine the emissions of gases and particulate matter during litter combustion.
- We highlight the potentiality of this facility to investigate emissions from fire.

ARTICLE INFO

Article history:
Received 27 November 2013
Received in revised form
5 May 2014
Accepted 6 May 2014
Available online 9 May 2014

Keywords:
Forest fires
Combustion chamber
Combustion gases
Volatile organic compounds emission

ABSTRACT

Biomass burning is an important ecological factor in the Mediterranean ecosystem and a significant source of several atmospheric gases and particles. This paper demonstrates the performance of a recently developed combustion chamber, showing its capability in estimating the emission from wildland fire through a case study with dried leaf litter of *Quercus robur*. The combustion chamber was equipped with a thermocouple, a high resolution balance, an epiradiometer, two different sampling lines to collect volatile organic compounds (VOCs) and particles, and a portable analyzer to measure carbon monoxide (CO) and carbon dioxide (CO_2) emission. VOCs were determined by gas chromatography–mass spectrometry (GC–MS) after enrichment on adsorption traps, but also monitored on-line with a proton-transfer-reaction mass spectrometer (PTR-MS). Preliminary qualitative analyses of emissions from burning dried leaf litter of *Q. robur* found CO and CO_2 as the main gaseous species emitted during the flaming and smoldering stages. Aromatic VOCs, such as benzene and toluene, were detected together with several oxygenated VOCs, like acetaldehyde and methanol. Moreover, a clear picture of the carbon balance during the biomass combustion was obtained with the chamber used. The combustion chamber will allow to distinguish the contribution of different plant tissues to the emissions occurring during different combustion phases.

1. Introduction

Vegetation fires, such as savanna and forest fires, domestic fuels and agricultural wastes burnings, release a great amount of trace gases as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrous oxide (NO) and volatile organic compounds (VOC) annually that could affect the atmospheric chemistry (Lobert et al., 1990; Miranda et al., 1994) through the "greenhouse" effect and the photochemical ozone formation (Hegg et al., 1987; Schultz et al., 1999; Koppmann et al., 2005). Biomass burning also exacerbates atmospheric particulate matter loadings (Ward and Hardy, 1991). This in turn leads to significant health implications, particularly for the respirable fraction (fine particles less than 2.5 μm in diameter) and impact on the Earth's radiative budget. By acting as cloud condensation nuclei, fine particles increase the cloud albedo partly counteracting the greenhouse effect (Delmas et al., 1995; Scholes et al., 1996; Reid et al., 2005). Particularly, low intensity fires produce high particulate matter emissions due to the agglomeration of condensed hydrocarbon and tar material, as well as the

* Corresponding author. Institute of Agro-Environmental & Forest Biology (IBAF), National Research Council (CNR), Viale Marconi 2, 05010 Porano, Terni, Italy.
E-mail address: carlo.calfapietra@ibaf.cnr.it (C. Calfapietra).

http://dx.doi.org/10.1016/j.atmosenv.2014.05.016
1352-2310/

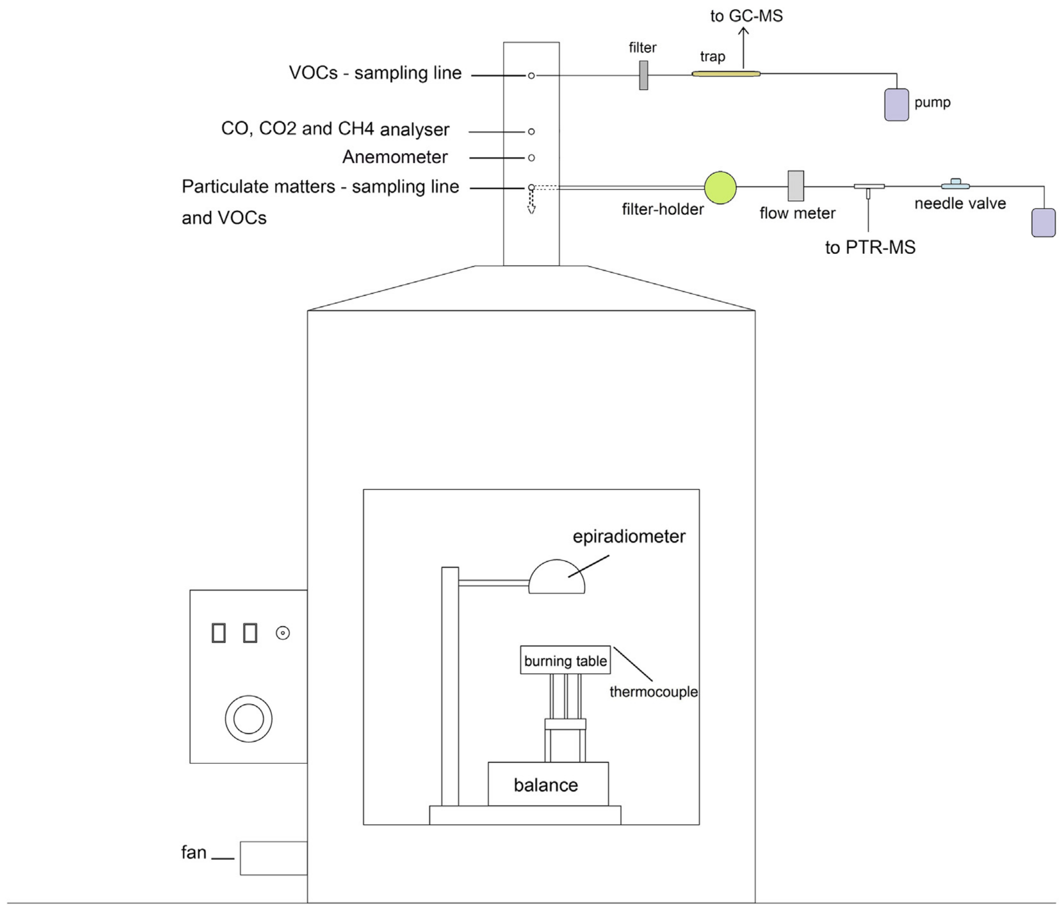

Fig. 1. Combustion chamber for laboratory biomass burning. The main components of the combustion chamber and the sampling lines of particulate matter and gases are indicated.

contemporary incorporation of ash and fragment of vegetation (Ward and Hardy, 1991). During the different combustion phases (pre-ignition, flaming and smoldering) of biomass burning a wide variety of products are formed. The pre-ignition stage is considered the period of time before the development of flame, when moisture together with some fuel pyrolysis products are released (Patterson and McMahon, 1984). The flaming stage is the phase of combustion associated with visible flame during which oxidized compounds, such as CO_2, CO, NO_x together with pyrogenic VOCs are emitted (Lobert et al., 1990). The smoldering phase begins after the flame extinction and a considerable amount of smoke is produced. It is characterized by high emission of CO (Ward and Hardy, 1991) and other less oxidized substances.

Fire represents a loss of stored terrestrial carbon. The sum of CO_2 and CO represents more than 90% of the carbon released during the biomass burning (Ward and Hardy, 1991; Andreae et al., 1998; Reid et al., 2005). As far as the carbon balance at ecosystem level is concerned, long-term effects of wildfires on atmospheric CO_2 are considered small because part of the emitted CO_2 is taken up by the biomass during the vegetation regrowth (Wiedinmyer and Neff, 2007), even though the burning of long rotation biomass (e.g. forest wood) can have some impact on climate because of the slow growth rate of this type of vegetation (Cherubini et al., 2011). Short-term effects of vegetation fires can be, instead, important as CO_2 emission can match or even exceed industrial emission at a regional scale (Amiro et al., 2001; Wiedinmyer and Neff, 2007). Due to the high variability of fire emission in both space and time as well as the uncertainty of emission and removal estimates (Chiriacò et al., 2013), the impact of forest fires on the carbon budget is difficult to be assessed at ecosystem level.

A number of studies have been carried out to assess the emissions from biomass burning. In some of them, the emission has been determined in combustion chambers where vegetation fires are carried out under controlled conditions (Lobert et al., 1990; Kannan et al., 2004; Zhang et al., 2008; Soares Neto et al., 2011; Warneke et al., 2011). Only with this approach it is, in fact, possible to follow in detail the combustion of the different vegetation compartments, such as leaves, bark, trunk, and the accumulated biomass in the soil, involved in forest fires. In addition to this, only experiments performed under controlled conditions allow to follow the progressive release of both reduced and various oxidized forms of carbon, such as CO_2, CO, CH_4, VOCs and particulate matter during the different phases of vegetation combustion, separating the contribution coming from pre-ignition, flaming and smoldering. This allows to get detailed information on the gas and particle emission originated from the combustion of plant species and vegetation compartments present in different forest ecosystems that can be useful for landscape management (Moreira et al., 2011). In this paper, a combustion chamber designed for the determination of gases and particles emitted from vegetation fire is described. Data collected during the combustion of *Quercus robur* dried leaves are presented to show the potential of this approach.

2. Materials and method

2.1. Description of the combustion chamber

A schematic diagram of combustion chamber designed at CNR-IBAF is shown in Fig. 1. The chamber was built by NOSELAB ATS s.r.l., Italy.