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Determination of polycyclic aromatic hydrocarbons in domestic pellet stove emissions

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ABSTRACT

Biomass is one of the most important renewable energy sources that could help to achieve the 2020 targets set by European Directive 2009/28. This is particularly true in Italy where the government plans to replace a final energy use corresponding to 200–250 PJ through the use of small wood stoves/boilers for domestic heating (<35 kW). This corresponds to about 25% of the national target for 2020. However, this solution is under discussion because of the environmental problems that poses in terms of emissions of PM and PAHs especially in lowland areas. The study, starting from these assumptions, was focussed to better characterize, with laboratory tests, the composition of PAHs emitted by a modern pellet stove and verify their distribution in the solid, liquid and gaseous fractions of the fumes at the stack. In brief, the tests showed that about 85% of the harmful effect of PAH is associated with the PM. This confirms that special attention should be given to the control of the dust through a better design of the stoves and/or the development of abatement equipment also suitable for small devices.

1. Introduction

Wood combustion for domestic heating is among the main sources of emission of volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAHs) and particulate matter (PM) which are linked to harmful effects on human health, such as cardiopulmonary disease and carcinogenic effects and, more in general, with the quality of the air [1–4]. In previous works, mutagenitic of the air in the areas in which the use of wood as fuel is widespread is positively correlated with the PAHs concentration in the air [5]. Moreover, PAHs are generally considered as an important cause of toxicity and mutagenicity of the PM [6,7], they have carcinogenic effects [8] and are strongly persistent and ubiquitous in the environment [9]. The quantity of PAHs in the atmosphere is mainly due to incomplete combustion of fuels based on carbon and hydrogen [10], such as vehicles fuels [11,12] and wood used for space heating [13–16]. With reference to wood, PAHs emissions depend on many factors like the temperature of combustion, the ratio air/fuel [17] and - in small stoves/boilers - are generally due to the less controlled conditions in which the combustion takes place [18]. According to some Authors, wood combustion could produce more PAHs emissions than any other fuel [19]. A recent survey conducted in Northern Italy [7] showed that, during the cold seasons, wood combustion produces from 30 to 70% of the PAHs associated to the PM_{10} of the ambient air. Emissions are generally higher during the nighttime.

Modern combustion technologies and high quality solid biofuels, like wood pellets, allow a better control of the emissions also in small devices and their widespread use can help to reduce the pollution of the air [18,20]. The use of modern pellet stoves is increasing in Italy and the pellet consumption is increasing from 150 kt in 2001, to 850 kt in 2008 [21] and is estimated at 1.2 Mt in 2009 [22].

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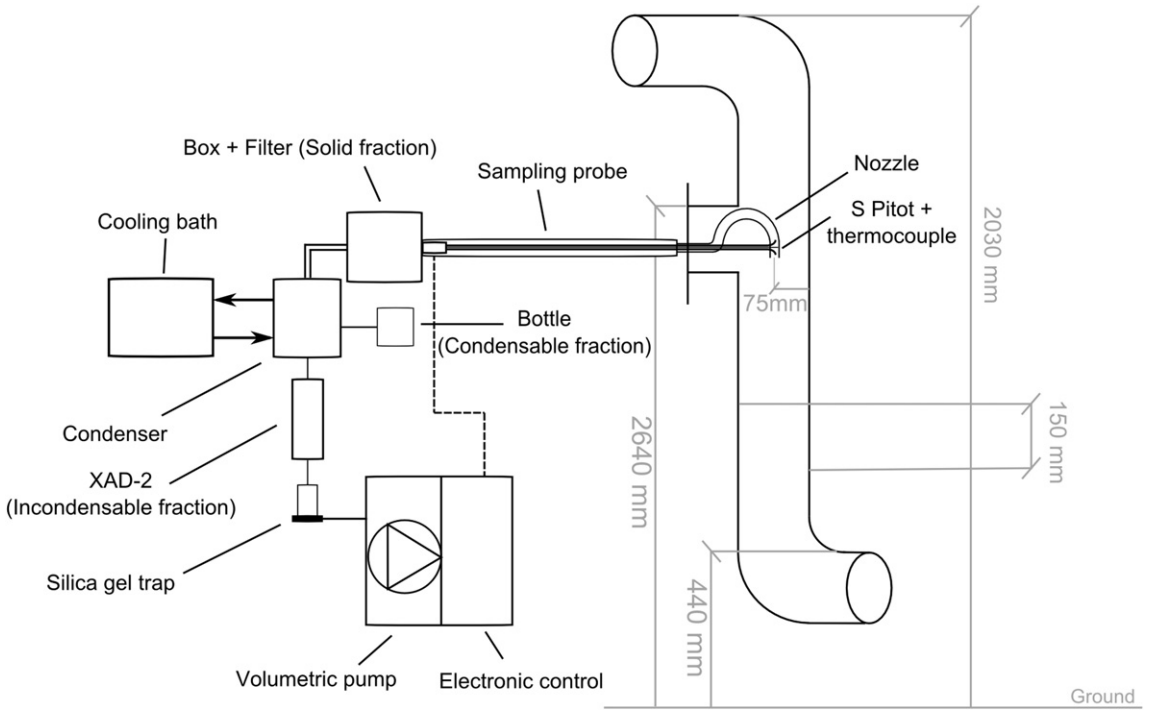

Fig. 1 – Sampling Train.

Many studies on the emissions produced by the biomass combustion for domestic heating are available [5,16,19,23–26] but few of them analyze the issue of the PAHs emissions produced by small pellet stove and there are few information about the distribution of the PAHs between the solid phase and the gas phase, which have different carcinogenic effects [27–29].

In Italy, the consumption of wood pellet in small heating devices is also encouraged by the national regulations aiming to foster the utilisation of renewable sources [30] but the environmental issues pose the need for a better understanding of the impact of these technologies and fuels on the environment and human health. In this context, this study aims to give a contribution through the discussion of the emissions of PAHs measured on a pellet stove tested in laboratory.

2. Materials and methods

2.1. *Pellet stove*

The device considered in this work is a top-feed pellet stove with a nominal output of 11.7 kW, manufactured in Italy. The model (mod. 6000AV, Caminetti Montegrappa) is representative of small household heating devices whose size is in the range not yet regulated by the Italian law [31]. The device is similar to that used by Sippula [32]: the fuel storage is embedded in the stove and wood pellets are supplied by a small auger screw to the burner. This is a cast iron cup with holes on the bottom for the passage of the combustion air that is driven by an electric fan. The stove can operate at five levels of power output modifying the pellet and the combustion air flow rates.

Table 1 – Pellet stove feed parameters at the two heat output settings studied.

Pellet Stove Parameters	P_{low}	P_{high}
Exhaust blower speed (Hz)	22	26
Feed rate (kg h^{-1})	1.3	2.2
Power (kW fuel input[a])	6.2	10.5

a Calculated according to the net heat value of the pellet as received (17.2 MJ kg^{-1}).

2.2. *Sampling of PAHs and PM*

The stove was installed in the Biomass Laboratory of the Polytechnic University of Marche and was connected to a chimney equipped with a sampling port designed in accordance to EN technical standards [33,34] (Fig. 1). All tests have been performed

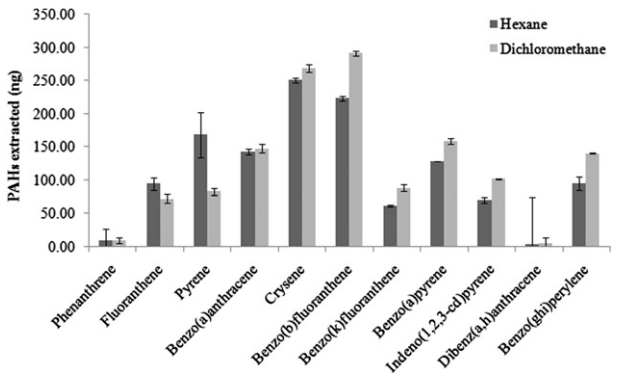

Fig. 2 – Comparison between hexane and DCM (solid fraction). Results obtained from three trials.