Environmental impact of biomass and polyethylene waste co-firing: emissions of particulate matter, PCDD/Fs and DL-PCBs

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Introduction

Biomass is fuel derived from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power. It is a CO_2-neutral fuel which offers an attractive renewable alternative for power plants. Biomass generally has a lower heating value than coal and this is due to its higher moisture and volatile matter (VM) content. High moisture content of biomass is one of the predominant factors in affecting the energy output and combustion performance [1, 2]. Rice husk is the most prolific agricultural residue in rice producing countries around the world. It is one of the major by-products from the rice milling process and constitutes about 20% of paddy by weight. Rice husk and rice straw are an attractive source of energy due to their chemical and physical properties [3]

Co-combustion of biomass with solid waste offers a number of economical and environmental benefits, such as alleviation of the problem of solid wastes disposal and recovery of their energy content [4].

The average EU recycling, reuse and recovery rate of plastics is about 20%, markedly lower than for other materials [5]. Polyethylene (PE) has the highest share of production of any polymer type; the percentages of non-recycled PE waste is allocated between three disposal options: landfill, incineration and mechanical biological treatment. In a study done by Eriksson and Finnveden [6], the swedish scientists concluded that burning plastic can give off less carbon dioxide equivalent than burying it in landfills.

The combustion or incineration of various wastes or natural materials containing chlorine can lead to the formation and emission of polynuclear aromatic hydro-carbons (PAHs), dioxins (PCDDs), furans (PCDFs), PolyChloroBiphenils (PCBs), chlorohydrocarbons and other species [7].

In this study, the emissions of particulate matter, dioxins and dioxin-like PCBs from a thermal power plant, feeded with biomass residues (i.e. rice husks), partially substituted by polyethylene waste , were investigated.

Materials and methods

Weekly tests were carried out in a 4-MW thermal power plant, that uses locally-obtained rice husks as feed and an Integrated Environmental Authorization allows the plant to use polyethylene waste for energy recovery. The power plant includes a bed combustion system with moving grate technology incineration furnace and a boiler, and a system consisting of a steam turbine, condenser and generator for the production of electricity. The plant is equipped with: i) a system of control of NOx emissions through proper temperature control and the injection of a solution of urea (SNCR), ii) a system of injection of sodium bicarbonate upstream of the dust collection system for reducing emissions of acid, and iii) a high-efficiency dust collection system (bag filter).

Particulate matter, PCDD/Fs and dl-PCBs were investigated; triplicate sampling followed UNI EN 13284-1:2003 and UNI EN 1948-1:2006, UNI EN 1948-4:2007, respectively. Before sampling the fumes at the emissions, the linearity of the continuous monitoring system at the plant was verified for macropollutants (CO_2, CO, O_2, SO_2, NO, NO_2, HCl, TOC).

Organic micropollutants were analyzed according to EN 1948-2, -3 and -4. Briefly, they were 36-h Soxhlet

extracted with toluene. Clean-up was performed by an automated system (J2 Scientific, Columbia, USA), based on Gel Permeation Chromatography, followed by an in-line automated concentrator and alumina column, as described by Rossetti et al. [8, 9]. The extracts were then concentrated and PCDD/Fs and DL-PCBs were analyzed by HRGC-HRMS on a GC 8000 series gas chromatograph (Fisons Instruments) coupled to an Autospec mass spectrometer (Micromass, Manchester, UK) in SIM mode. The GC-MS identification and quantification were made by the isotope dilution method. The particulate matter was evaluated via gravimetric analysis.

Results and discussion

The amount of plastic waste introduced into each campaign was defined taking into account the lower heating value (LHV) of each fuel (in consideration of moisture of the material), since the percentage of PE is referred to the energy content. Table 1 shows the average concentrations ($n=3$) of particulate, total PCDD/Fs and total dl-PCBs, referring to 11% oxygen, and the amount of PE waste added in each campaign.

An analysis of the distribution of the congeners of both PCDD/Fs and DL-PCBs, shows a similar fingerprint for each sampling campaign, with Tetra- and Penta-chlorinated furans and PCB-126 and PCB-169 predominant contribution on the total TEQ concentration (data not shown).

A correlation between PM and total TEQ chlorinated pollutants has been investigated, taking into account the contribution of PCDD/Fs and PCBs in each campaign. Figure 1 shows the mean distribution of PCDD/Fs and PCBs with respect to the PM concentration. It can be observed that the contribution of PCDD/Fs is predominant: 70-80% up to 10% of PE. DL-PCBs contribution became 50% when rice husk is substituted with 15% of PE.

As a further step, the determined concentrations were combined with data of consumption of plastic waste (kg over 24 hours total) and flow rate on days when the samples were performed, provided by the plant owner. Therefore, it was possible to estimate an "emission factor" (EF), defined by the Italian Legislative Decree 152/06 as "the amount of pollutant emitted referred to the production process considered in its totality and in its technological phases, expressed in terms of mass of pollutant emitted, compared to the mass of product or raw material, or any other parameters suitable for representing the production sector concerned". Figure 2 shows the average emission factor of each class of pollutant, expressed in pg TEQ/kg PE, in each experimental campaign. It can be observed an inversely proportional trend: the emission factor is lower with PE increasing rate, and it is more evident with PCDD/Fs .

Conclusions

The study allowed us to outline the environmental impact in the use of polyethylene waste in a biomass (rice husks) fueled plant, aimed at energy recovery. It is reasonable to assume that concentrations of pollutants have remained almost unchanged by introducing PE in feed for low halide halides and metals contained in the waste itself.

The combustion of polyethylene waste presents a profile of environmental sustainability higher that of the other plastic compounds (eg PVC), as these materials are made up of straight chain hydrocarbons free of halogens.

References

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	PE	PM	PCDD/F	dl-PCB
	[%]	[mg/Nm³ ref. 11% O$_2$]	[pg TEQ/Nm³ ref. 11% O$_2$]	[pg TEQ/Nm³ rif. 11% O$_2$]
I	0	16	0.614	0.174
II	5	11	0.882	0.427
III	10	24	1.242	0.122
IV	15	12	0.747	0.645
V	10	15	0.759	0.235
VI	5	29	0.765	0.225

Table 1. concentration of PM, PCDD/Fs and dl-PCBs with respect to PE rate
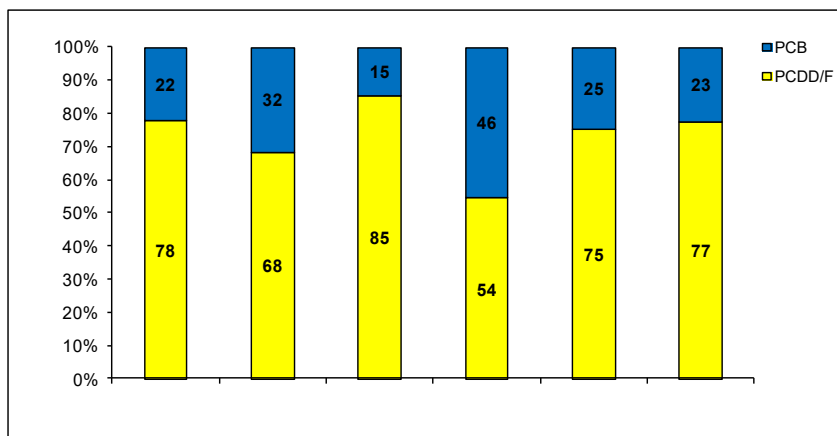

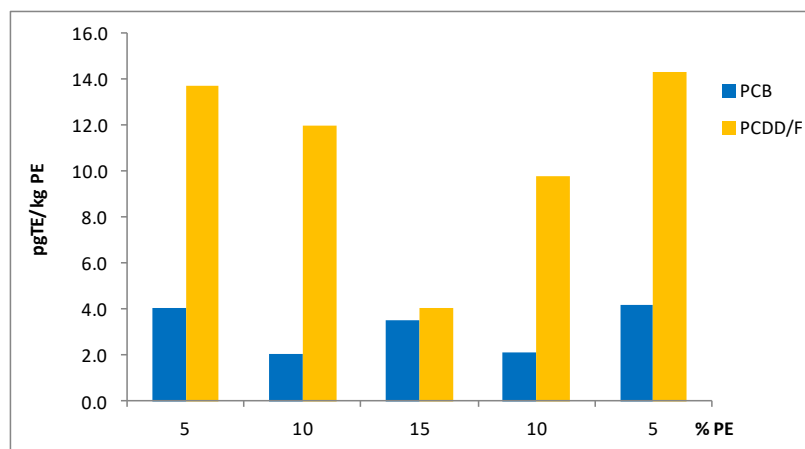**Figure 1** – Average contribution of PCDD/Fs and dl-PCB to the PM concentration

Figure 2 – Average emission factors (pgTE/kg PE)