

PCDD/F EMISSIONS DURING LIGNITE - BIOMASS WASTEWOOD CO-COMBUSTION IN A MOVING GRATE INDUSTRIAL COMBUSTOR

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Introduction

Combustion of fossil fuels is used today worldwide for energy production, but it results in significant release of CO₂ in the atmosphere. A net decrease of CO₂ emissions can be achieved by the thermal use of regenerative energy sources such as biomass and biomass byproducts. Especially co-firing biomass waste and coal, offers a number of technical, economical and environmental benefits in addition to reduced net CO₂ emissions, such as conservation of fossil fuel resources, minimization of waste disposal and reduction of the dependence on fuel imports.

Although co-combustion of waste wood with coals is a promising technique, it entails some environmental risks due to the chemical nature of waste wood. Waste wood is usually impregnated with a number of substances, which can result in the release of toxic compounds like dioxins and furans. Since the early 1950s, pentachlorophenol (PCP) and lindane have been used as wood preservatives, because of their fungicide and insecticide properties¹. Organic substances and especially PCP are known precursors of PCDD/F during combustion processes². Furthermore, unchlorinated PCDD/Fs have been observed in the lignin structure, which could result in the production of the chlorinated compounds through simple chlorination reactions³. The concentration of chlorinated organic substances, emitted during co-combustion of coal-waste wood depends on the type of solid fuel, the type of the combustor and the operating conditions^{4,5}.

The objectives of this work were to determine the PCDD/F emissions during co-combustion of waste wood and a low grade lignite in an industrial scale combustor, to compare them with emissions from co-combustion of natural wood, and to correlate gas emissions with the fuel mixture properties.

Material and methods

Co-combustion experiments were performed in an industrial boiler, located at a wood processing plant in Northwestern Greece. The boiler capacity was 13.8 MW_{th} and consisted of a two compartment combustion chamber. The first one employed a moving stoker system able to operate with saw dust and wood chips. This compartment covered about 50-60 % of the total thermal input, with a fuel consumption up to 5 ton of fuel/h. The second compartment had a multi-

fuel burner employing sawdust or oil. Raw gases from the second compartment passed through a multi-cyclone system and then they were led to the stack.

The coal used in the co-combustion experiments was lignite from the Ptolemais seam, Greece. MDF powder which was a byproduct of the production process, and wood poles used for power transmission, were used as a waste wood source. Pine wood chips were also used as a natural wood source. The proximate and ultimate analysis of the various fuels is shown in Table 1. Co-combustion tests were performed by feeding the desired fuel mixtures in the first compartment of the boiler. Fuel feed and air flow rate were regulated in order to maintain complete combustion conditions and a low content of CO in the flue gas stream.

Table 1. Proximate and ultimate analysis of lignite and biomass fuels (% w/w, dry basis).

Element	Ultimate analysis			
	Lignite	Natural Wood	Power Poles	MDF
C	49,96	39,58	45,34	46,49
N	1,26	0,08	0,18	2,37
H	4,65	5,17	5,38	5,98
S	1,06	0,19	0,00	0,30
O	32,27	54,13	48,20	44,32
Proximate analysis				
Volatiles	58,40	94,00	84,40	90,10
Fixed Carbon	30,80	5,15	14,70	9,36
Combustibles	89,20	99,15	99,10	99,46
Ash	10,80	0,85	0,90	0,54

Gaseous samples were collected from the flue gas duct after the multi-cyclone unit and before the air draft fan. The sampling unit for PCDD/F was based on the cooled probe method and sampling was performed under isokinetic conditions, according to VDI guideline 3499⁶. Analysis and quantification of PCDD/F were performed in the extracts by using a mixed silica column and an alox column⁷. PCDD/F measurements were performed in a HRGC/HRMS system (HP5890/MAT 95 Finnigan). The recoveries of certain isomers ranged between 60 and 95%.

Results and discussion

Various fuel blends were prepared for performing the co-firing tests, and the corresponding concentrations are given in Table 2. Total concentration and TEQ values of PCDD/F emitted during the co-combustion tests are also given in Table 2. TEQ values, in almost all cases, were lower than the limit value of 100 pg/Nm³, and ranged between 3 pg/Nm³, in the case of MDF/lignite 80/20, to 97.3 pg/Nm³ for the combustion of 80/20 natural wood/lignite mixture. The results obtained from separate analysis of PCDD/F in the XAD resin cartridge and in the quartz glass wool cartridge during the combustion of pure wood, showed that PCDD/F were mainly adsorbed on the surface of the soot particles, which were collected in the first quartz wool cartridge. Only a small part of the total PCDD/F concentration, about 3%, was present in the gaseous form, and it was trapped in the second cartridge. A duplicate experiment of pure MDF

combustion was performed under complete combustion conditions, and the measured TEQ values were close, about 55 and 72 pg/Nm³ from the two tests.

An elevated TEQ value of about 4 ng/Nm³ was measured during the co-combustion of power poles with natural wood in a ratio of 50/50 w/w. This high value could be attributed to the presence of the power poles, which were impregnated with additive compounds as wood preservatives. Furthermore, during this experiments, difficulties in the fuel mixture handling and feeding, resulted in uncompleted combustion conditions. However, combustion of mixtures containing 20% power poles, resulted in TEQ values lower than 0.1 ng/Nm³.

The data from the co-combustion of natural wood, show that there is no direct correlation between the TEQ values and the percentage of wood in the solid fuel. However, the lowest TEQ values were observed during the co-combustion of lignite/MDF mixtures (3 pg/Nm³) and pine wood/MDF/lignite (6.2 pg/Nm³). It is possible that MDF contained such compounds as urea and formaldehyde, which could inhibit the formation of PCDD/F in the flue gases. There is evidence that the addition of some nitrogen compounds in the post combustion zone, can effectively reduce the concentration of PCDD/F in the flue gases, although the mechanism of this inhibition has not been completely resolved⁸.

Table 2. Fuel blends used in co-combustion tests and PCDD/F emissions.

No	Date	Fuel	Content %w/w	Total conc. pg/Nm ³	TEQ pg/Nm ³
1	15/10	Pine Wood	100	7802	78,3
2	21/10	MDF	100	5238	54,7
3	30/10	MDF	100	4718	71,9
4	20/10	Pine Wood/Lignite	80/20	10671	97,3
5	16/10	Pine Wood/Lignite	60/40	10202	47,1
6	24/10	MDF/Lignite	80/20	748	3,0
7	25/10	Power Poles/Pine wood	50/50	240044	4171
8	29/10	MDF/Lignite/Power Poles	60/20/20	7282	82,8
9	27/10	Pine Wood/Lignite/ Power Poles	60/20/20	6801	71,2
10	28/10	Pine Wood/MDF/Lignite	60/20/20	894	6,2

The homologue patterns for tetra to octa-chlorinated dioxins and furans are shown in Figures 1 and 2 respectively. The results in these figures follow the same trends like the corresponding data presented in Table 2. The highest values of chlorinated dioxins and furans were observed during the co-combustion of the mixture of power poles with natural wood.

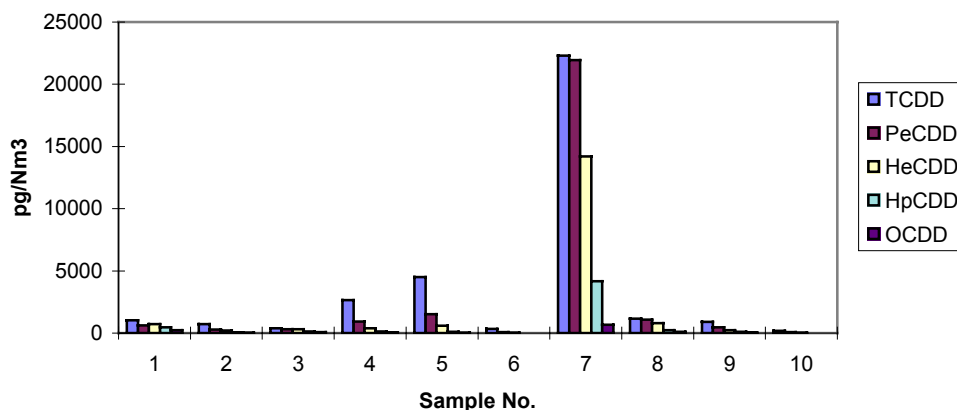


Figure 1. Homologue pater of dioxins for waste wood/lignite co-combustion.

Furthermore, as shown in Figure 2, furan concentrations were higher than the corresponding dioxin concentrations, and the ratio of PCDD:PCDF ranged between 1:2 to 1:3. However, for the combustion of natural wood and the co-combustion of natural wood and lignite, the dioxins prevailed over the furans and the corresponding ratio values of PCDD:PCDF were about 1:0.5 to 1:1.5. It seems that wood combustion changed the distribution of PCDD/F's; it is known that both the formation and distribution of PCDD/F's depend on burning conditions and waste composition⁹. In addition, as shown from the homologue patterns in Figures 1 and 2, the lower chlorinated congeners prevailed over the higher chlorinated, in accordance with typical homologue patterns from combustion processes.

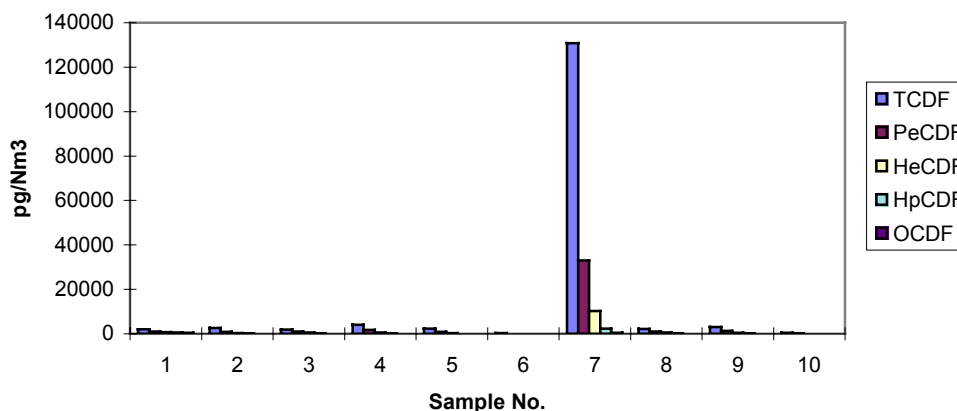


Figure 2. Homologue pattern of furans for waste wood/lignite co-combustion.

Conclusions

Co-combustion tests of waste wood (power poles, MDF, pine wood), and low-grade lignite were performed in an industrial moving stoker unit, in order to examine the gas emissions and to study the potential of disposal and utilization of waste wood for energy production. In most cases, co-combustion of waste wood and lignite resulted in low PCDD/F emissions, lower than the limit value of 0.1 TEQ ng/Nm³. However, co-combustion of natural wood and power poles resulted in high emissions of about 4 ng/Nm³. The lowest emission values were observed during co-combustion of MDF dust, possibly due to an inhibition effect by some of the MDF ingredients.

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