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Full Length Article

An extensive characterization of various treated waste wood for assessment of suitability with combustion process

Maïté Huron [a], Sophia Oukala [a], Jérôme Lardière [b], Nicolas Giraud [b], Capucine Dupont [a,*]

[a] Université Grenoble Alpes, CEA – LITEN, Laboratory of Pretreatment of Bioresources, Grenoble, France
[b] CCIAG, Grenoble, France

HIGHLIGHTS

- Extensive characterization was performed on a large panel of waste wood samples.
- Waste wood heterogeneity was confirmed.
- The pollutants concentration could be explained by the wood treatments.
- Ash, moisture and iron contents were mainly linked with external pollution.
- N, Cl and metals were found to be the main obstacles to combustion.

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ABSTRACT

A representative set of treated waste wood was extensively characterized in order to evaluate its heterogeneity and its suitability with combustion process. Samples included both average samples made up of waste wood mixtures and specific waste wood classes. Untreated wood was also considered for comparison.

As expected, neither heating value nor composition in C, H, O varied significantly compared to untreated wood. However, differences arose for minor elements, in relation with the chemical treatments undergone by waste wood.

Particleboard was shown to be the main source of N with values up to 38 g/kg due to the presence of N-containing resins. Heavy metals like Ba, Ti or Zn were clearly associated to pigments used in painted wood or coatings and their amount reached respectively 2.6, 2.9 and 1.1 g/kg in painted wood. Cr and Cu were shown to come essentially from the chemical treatment undergone by impregnated wood with values of several thousands of mg/kg.

A comparison between the minor elements contents found in waste wood and the specifications required in terms of feedstock composition and gas emissions in biomass combustion plants showed that the use of such feedstock would require either pretreatment before combustion to remove impurities or specific gas post-treatment.

1. Introduction

Wood is known to be the most suitable biomass type for combustion process because of its relatively high density, high heating value, low ash yield, small amount of low temperature melting elements in ash and low impurities amount [27,28]. However, the amount of wood is limited and this resource faces severe competition of uses between pulp, construction and energy applications [21]. In this context, waste wood products, coming from furniture, construction or industry, appear as very promising feedstock for combustion since a large amount of this resource remains unused at the moment [5].

This feedstock is yet highly heterogeneous and even the definition of waste wood varies according to country. Waste wood can be split into three categories: clean untreated wood, slightly treated wood and heavy treated wood [4].

Clean untreated wood includes packaging like pallets or wooden boxes and is already used in combustion units. Heavy treated wood such as woods impregnated with preservatives such as creosote or copper chromium arsenic (CCA) is in most cases considered as hazardous waste and has already been extensively

* Corresponding author.
E-mail address: Capucine_dupont@hotmail.fr (C. Dupont).

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studied in literature [20]. In this study, the focus was therefore put on slightly treated wood, which represents a large part of waste wood [5] and which is not considered as hazardous. It is mainly constituted i) of products manufactured with resins or adhesives, *i.e.* particleboards (PB) and plywood, ii) of wood that was surface-coated with paints, stains, plastic laminates and iii) of wood treated with fungicide or water repellents. A large variety of chemical elements are involved in wood treatments [2]. For example, paints and preservative are typical sources of heavy metals, N is implied in panel resins, and halogens are found in some coatings. All these chemical elements can be dangerous for human health and for environment when wood is burnt, in particular due to the emission of NO_x, SO_x, dioxins and volatile organic compounds [23]. To avoid these emissions, more severe gas cleaning may be applied in combustion plants. However, such extra gas cleaning means extra cost for the plant. Moreover legislation also limits the authorized amount of these elements in biomass fuel before combustion, for instance in France [15,16] and these elements may also cause technical problems during combustion. For example, halogens, Pb and Zn may induce high-temperature corrosion, while alkali are known to increase the risk of bed agglomeration and sintering.

As a consequence, it is of great importance to characterize the chemical composition of slightly treated waste wood and to determine the pollutants origin to assess suitability between treated wood waste and combustion process for further design of appropriate pretreatment before combustion as well as of gas post-treatment.

However, only few studies were carried out on this topic. Most studies focused on the design of pretreatment of one specific type of waste wood. Girods et al. [3,11] studied for instance the impact of nitrogenous compounds on panel pyrolysis. Several authors [12] focused on CCA treated wood because of its high toxicity. Other teams chose to compare different kinds of waste wood. Tatano et al. [22] and Yorulmaz and Atimtay [25] studied pyrolysis of Medium Density Fiber, plywood and particleboard while Khalfi et al. [13] investigated the impact of paraffin and adhesives on fir wood incineration. In all cases, the samples were not representative of the diversity of waste wood and analyses were limited to compounds relevant for the kind of wood considered. In particular, heavy metals other than Cr, Cu and As were rarely investigated.

To our knowledge, only three recent studies attempted to characterize waste wood in an extensive manner. Edo et al. [7] reported very detailed elemental analysis of a huge number – five hundred – of waste wood samples used as feedstock in an industrial heating plant along nine years. Indeed, the objective of the study was mainly to assess waste wood variability with time. Strong heterogeneity was clearly shown. Besides these measurements, an effort was made to establish the relative contribution of the different material contaminants, such as stone or concrete. However, no indication was given on the type of waste present in their samples and consequently they did not link the pollutant content to specific families of waste such as panel or painted wood. In a similar way, Moreno and Font [14] carried out complete analysis of furniture waste wood. Moreover, they compared the results with untreated wood and performed pyrolysis tests. They established that additives present in furniture wood waste impacted thermal processes but, as Edo et al. [7], they did not give any indication on the type of waste present in their samples and consequently they did not link the pollutant content to specific families of waste such as panel or painted wood. Eventually, in the study from Fellin et al. [10], the objective was to test the method of Energy Dispersive X-ray Fluorescence (ED-XRF) for obtaining elemental analysis of waste wood samples. Indeed, this method was initially developed for other materials than wood. A wide range of waste wood was sorted according to their origin, type, typology, visual detection of pollutant and pollutant macro-category. However, they limited their study to the elements considered as the most relevant in terms of ecological concern. This included heavy metals but excluded other crucial compounds such as N or S. Furthermore, XRF is a very matrix-sensitive surface analysis technique and detection limits of ED-XRF appeared to be too high for some important elements (Cl, Cr, Sn and Ti) contrary to the limits associated to the standard methods used for solid biofuels characterization (ICP/MS, ICP/AES and ionic chromatography).

Waste wood has thus never been extensively and completely characterized following measurement standards on solid biofuels in order to evaluate its heterogeneity and its suitability with combustion processes. This study aimed at filling in this gap through the characterization of a representative set of waste wood sorted into different classes defined according to treatment undergone and thus possible contaminants. The results obtained were systematically compared with untreated wood and unsorted mixtures of waste wood. As a reference, the French legislation on biomass combustion units was also used to discuss results.

2. Material and methods

2.1. Wood samples

Waste wood samples were collected in the waste recycling center of Goncelin (France). In order to determine which kind of waste wood contains more pollutants and the maximum concentrations that can be reached in waste wood, they were sorted out into 9 classes:

- Laminated timber, which is composed of timbers glued together without chemical additive
- 4 types of panels, which are wood particles glued with resins:
  - o Raw particleboard
  - o Coated particleboard
  - o Particleboard treated on surface
  - o Coated and treated plywood
- Painted wood (containing heavy metals)
- Painted wood produced before 1990, as several painting elements (Hg, Pb) have been forbidden at this time
- Wood coming from old furniture, which is also likely to contain compounds that are not allowed anymore (As, Hg, Pb)
- Impregnated wood. This kind of wood, which is treated with copper chromium arsenic (CCA) or copper chromium boron (CCB), is part of the highly treated wood and is thus beyond the scope of our characterization study. However, this class has been considered as impregnated wood can be sometimes mixed with slightly treated wood in collecting centers.

Shredded wood pallets were also included in the study. They were provided by the company CCIAG and mainly contained softwood.

Average samples containing all classes unsorted were also considered. They are representative of the real feedstock that may be used in combustion units. Each contaminant is expected to be present in lower concentration in these samples than in the worst class identified above. One average sample was obtained by gathering equal fractions of each previous class except wood pallets (Average 1). Five average samples were obtained by randomly taking waste wood without any sorting in different French waste wood recycling centers and at different periods. One sample was collected in Albertville center (Average 2), another one in Saint Quentin-sur-Isère (Average 3) and the last ones in Gresivaudan during three different weeks (Average 4, 5 and 6).

To test the influence of antifungi products, two samples were directly treated in the lab from raw wood, since antifungi products