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Quality assessment of recycled wood with and without non-wooden materials from selected recycling companies in Europe

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ABSTRACT

Recycled wood is becoming an important material source for production of new materials and chemicals. Predominantly clean recycled wood should be used for the products with high added value. However, contamination of the recycled wood defines the potential end uses. Thus, it is of the huge commercial and environmental importance to monitor the contamination of the respective material. In the present research, we focused on concentrations of non-wooden materials in recycled wood and the presence of indicative inorganic pollutants, namely: chlorine (Cl), chromium (Cr), copper (Cu), zinc (Zn), lead (Pb), iron (Fe) and bromine (Br). Sampling of various qualities of commercially available recycled wood was performed for one year in recycling companies from Germany, Slovenia, Finland and UK. In addition to the above-mentioned long term monitoring, fraction analysis was also performed on selected batches. For nine different fractions, the water soluble part and lignin content were additionally determined. The results showed that high quality recycled wood had low shares of non-wooden materials and only a few samples exceeded the limit values for inorganic pollutants prescribed by German ordinance Altholzverordnung or EPF standard. On the other hand, mixed recycled wood, of lower quality contained a significantly higher portion of non-wooden material (up to 3%). These mixtures also had higher concentrations of inorganic pollutants. More than 85% of samples exceeded the limit concentration prescribed by the German ordinance Altholzverordnung for recovered wood for at least one of the analysed chemicals. The concentration of chemical elements in samples from nine different size fractions negatively correlated with the particle size in the fractions. The same trend was also observed for the soluble part and the lignin content. In general, it can be concluded that recycled wood deriving from larger annual process capacity volumes with sophisticated sorting systems, contains less non-wooden material and can provide clean wood. On the other hand, the mixed recycled wood contained high concentrations of inorganic elements, regardless of the origin or sorting system.

1. Introduction

Demand for wood and wood based products from natural forest resources is increasing, mainly because of population growth, political changes, increased environmental awareness and a shift of EU policies to the circular- and bio-economy. Despite wood being a renewable raw material, forest resources are limited. For a more sustainable and resource efficient use of wood, a multistage cascading use of recycled wood is needed and desired (Vis et al., 2016). The cascading use of recycled wood as a secondary resource prior to energy recovery is a solution for preventing forestry resource and price volatility (Höglmeier et al., 2014, 2013). Although cascading is an approach that was introduced more than decades ago, there are still many opportunities to increase its use (Vis et al., 2016). In Germany in 2010, around 80% of recycled wood was used for energy production. The second most important use of recycled wood was particle- or fibreboard production (Mantau et al., 2012). There are also other alternatives for using recycled wood, such as the production of wood plastic composites (Sommerhuber et al., 2015) or bio-chars production (Sadasivam and Reddy, 2015).

Use of recycled wood in bio-refineries for the production of bio-based products is one of the promising possibilities for the cascading use of wood (Vis et al., 2016). However, there are some challenges related to the quality of recycled wood (Lesar et al., 2016). In typical bio-refineries, the composition of incoming raw material is known and constant, whereas the composition of recycled wood is unknown and can vary from delivery to delivery, depending on

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the source of the recycled wood (Bouslamti et al., 2012; Krook et al., 2008, 2006; Edo et al., 2015). Recycling companies receive recycled wood from various sources. In general, they sort incoming material based on the origin and visual appearance, using a strict guidance protocol. Additionally, they have internal sorting systems for recycled wood. There is no common European legislation related to old, waste or recycled wood, so the majority of the recycling companies in Central and Eastern Europe follow criteria based on the German waste wood regulation - Altholzverordnung (2002) (Vis et al., 2016). Despite the strict control of recovered wood in recycling companies, some non-wooden materials (plastic, metals, stones, paper, cardboard, etc.) can appear also in a recycled wood mixture (Edo et al., 2015). Beside non-wooden materials, also some wood based materials have to be avoided in recycled wood for material use, like fibreboards or treated wood. The sorting methods currently used are robust industrial processes and it is almost impossible to avoid pollutants and other contaminants in recycled wood entirely (Edo et al., 2015; Hladnik, 2009; Lesar and Humar, 2014).

Despite huge development in sorting technologies, it should be born in mind that no sorting procedure is 100% efficient (Vrancken et al., 2017). The issue related to contaminants is that some of the contaminants, such as metals and plastics, can cause damage to equipment during processing. The worst-case scenario is that contaminants appear in the final product that can potentially influence its properties. For wood recycling three main online sorting technologies have been studied in recent years, laser induced breakdown spectroscopy (LIBS) (Martin et al., 2005; Moskal and Hahn, 2002; Solo-Gabriele et al., 2001), X-ray fluorescents technology (Hasan et al., 2011a, 2011b; Solo-Gabriele et al., 2004) and optical–near infrared spectroscopy (Mauruschat et al., 2016). The majority of these approaches have focused on detection of heavy metals used in biocides, such as Cu, Cr and As (Martin et al., 2005; Moskal and Hahn, 2002; Solo-Gabriele et al., 2001, 2004; Hasan et al., 2011a, 2011b). Online sorting technologies enable real-time analysing, sorting and elimination of undesirable materials from recycled material during recycling process. None of these technologies has yet been successfully applied in European waste wood recycling plant, while such technologies are common in other recycling facilities like glass or plastic recycling.

Fairly high temperatures are applied in pre-treatment processes in industrial bio-refineries (Michels, 2014). At high processing temperatures, plastic contaminants can melt and later block pipe systems or pumps in reactors, and can potentially decrease the quality of products (Lesar et al., 2016). Metal parts such as nails and screws can be extremely harmful for pumps and other process equipment. Wood composites, such as particle boards and veneers, also contain synthetic resins and/or coatings (Lykidis and Grigoriou, 2008), which cannot be processed to target products, thus reducing the overall efficiency of the process. Another source of pollutants is wood preservation. There has been a huge spectrum of active ingredients used in the field of wood protection in the last century (Freeman et al., 2003; Jacoby and Freeman, 2008). One of the most important wood preservative practices in Europe was the application of CCA (wood preservative based on Cu, Cr and As compounds), which was later replaced with copper amine systems (Richardson 1997). Various guidelines have been introduced to avoid these problems. In Europe, there are three of such documents; (1) German ordinance Altholzverordnung (2002), which is the German guideline for recycled wood sorting. Altholzverordnung has also been adopted in some other countries, e.g. Slovenia. Altholzverordnung divide recycled wood in four main categories A I - only mechanically treated, A II - surface treated without halogenated organic compounds, A III - surface treated with halogenated organic compounds and A IV - treated with biocides. Because of the difficulty to distinguish between A II and A III category recycling companies do not sort to four groups but only tree (A I, A II, A III mix and A IV). Another very important document is the voluntary standard launched by the European Panel Federation EPF: The use of recycled wood for wood based panels (EPF standard, 2002). This guideline is a based on the European Commission decision for eco-labelling for wooden furniture (2009/894/EC, 2009). In general, the EPF standard prescribes higher limit values for pollutants in recycled wood than the German ordinance Altholzverordnung. The same limit values as prescribed by the EPF standard for recycled wood for panel production are also used by the UK standard (PAS 111, 2012). Specification for the requirements and test methods for processing waste wood. Standard grade recycled wood is divided into four categories (A clean recycled wood, B industrial feedstock, C fuel and D hazardous waste).

The aim of this research is to characterize recycled wood on the European market in terms of regional and seasonal perspective. Although there has been some studies about contamination of recycled wood already performed, is this the first comprehensive research that has been performed in four different countries through longer period In respective study, we focus on much wider area where recycled wood was collected. In addition, analysed countries and respective companies involved utilises different sorting systems for wood recycling and management systems. Objectives of the research was to get information about the quality of recycled wood on the market that can be used for further processing preferably in biorefineries or production of wood based panels. Utilisation of recycled wood for energy production is the least preferred option. In addition, we were interested also how composition and season of recycling influence on final quality of recycled wood. As the German ordinance for recycled wood is the most comprehensive, the authors of the present research used Altholz and EPF limits also for A I–A III recycled wood mixture, which offers large possibilities of using more recycled wood for material production. Our investigation is intended to show how clean recycled wood can be with today's sorting and cleaning techniques. First hypothesis were that quality of recycled wood differ between countries and is influenced by company size. Second one recycled wood, which was collected and recycled in different periods of the year (seasons) has different qualities. Beside this on quality influence also particle size of the recycled wood. The quality of the recycled wood material is a first important indication that helps to identify new alternative processing routes to existing uses, which will probably result in an increased demand for recovered wood and supports the diversification of off-take products for the wood recycling business throughout Europe.

2. Material and methods

2.1. Sampling

Different types of recycling wood were collected from recycling companies in Germany (G), UK (E), Finland (F), Slovenia (S1) and a public utility company from Slovenia (S2) (Table 1). The collection of recycling wood was performed by recycling companies as part of their usual selection of recycled wood material. Sampling was performed for one year, in period between September 2014 and October 2015 in German company (every two weeks) and Slovenian companies (every two to four weeks) and in Finish and UK companies sampling was performed only once in May 2015 (Table 1). For sampling, chipped recycled wood material (maximal dimension 5 cm) was taken at all sites from at least five different parts of large piles of wood chips. From every part of the pile 10 L of wood chips was taken. The material was then mixed and a two parallel representative samples of 5 L was collected from this mix and sent for analysis. Pure softwood and hardwood chips from a Slovenian company (S1) were taken as control.