Wood ash – a potential forest fertilizer

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1 Introduction

The enhancement of wood-derived energy plays an important role in the Finnish energy and climate strategies (Alakangas, 2001). The use of new and upgraded biomass fuels, e.g. pellets and briquettes, has become more common in recent years, especially fuel pellets which are well suited for home heating applications. Although electrical and district heating are still the most popular heating systems in news detached and row houses in Finland, stoves and fireplaces which burn biomass fuels, e.g. logs, pellets and briquettes, are commonly used as a secondary heating system. It has been estimated that about 100 000 wood fired heating systems are currently in operation in Finland. Thousands of small-scale boilers are sold annually, and about 30% of the wood heating systems are fuelled by wood chips or pellets (Alakangas, 2001). Compared to traditional firewood, pellets provide possibilities for automation and optimization in the same way as for oil, with high combustion efficiency and small combustion residues. In addition, wood pellets can be stored and traded at the regional, national and international level. These features, combined with the other advantages such as environmental benefits (i.e. CO_2 neutral fuel), low moisture content and bulk density (i.e. 0.28 bulk-m^3 of wood pellets is equivalent to 1 bulk-m^3 of wood chips), as well as a relatively high heating (i.e. calorific) value (about 17 MJ/kg), which allows long-distance transport without affecting the energy balance make wood pellets attractive in many countries from both the demand and the supply side of the market (González et al., 2004). Wood ash usually contains mineral plant nutrients, especially base cations (e.g. Ca, Mg, K), and has a strongly alkaline pH. For this reason, it would be ecologically beneficial if the ash that contains plant nutrients could be returned back to the forest ecosystem. This would save primary resources and can be seen as an example of the sustainable use of biomass.

2 Objectives of the research and methods

The purpose of this study was to determine the physical and chemical properties of wood pellet ash originating from a grate-fired boiler at a small-scale (100 kW) heating plant at Kuusamo, Eastern Finland, incinerating commercial wood pellets manufactured from wood material collected in the Kuusamo region. The district heating plants produces energy for three houses, which total heating area is ca 1100 m^2.

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The ash was sampled from the grate-fired boiler at a small-scale district heating plant at Kuusamo, Eastern Finland. The plant has a 100 kW boiler, and 100% of the energy produced by the boiler originates from the incineration of commercial wood pellets. The boiler incinerates ca. 40 tonnes of commercial wood pellets per year expressed on a dry weight (d.w.) basis. The commercial wood pellets incinerated in the boiler were made from cutter shavings and sawdust (ca. 80–90% pine and ca. 10–20% spruce) originating from the mechanical wood-processing industry in the Kuusamo region.

Determination of the pH and EC were carried out according to the European standard SFS-EN 13037 at a solid to liquid (S/L) ratio of 1:5 (v/v). Determination of the dry matter content of the ash was carried out according to the European standard SFS-EN 12880. The loss-on-ignition (LOI) value was determined according to the European standard SFS-EN 12879. Determination of the total organic carbon (TOC) concentration in the ash was carried out according to the European standard SFS-EN 13137. Determination of the neutralizing (NV, liming effect) and reactivity (R) values were carried out according to the European standard SFS-EN 12945 and SFS-EN 13971, respectively. A comprehensive review of the standards, analytical methods and instrumentation is given in a previous study (Nurmesniemi et al., 2008).

Determination of easily soluble nutrients such as Ca, Mg, Na, K, S, P, Mn, Cu and Zn in the ash was carried out according to the procedures of MTT Agrifood Research Finland (Nurmesniemi et al., 2008). The concentration of P in the extract was determined spectrophotometrically by the molybdenum blue method using an automatic Foss – Tecator FIAStar 5000 Flow Injection Analyser (Högnes, Sweden). The concentrations of Ca, Mg, Na, K and S were determined by inductively coupled plasma optical emission spectrometer (ICP/OES, Thermo Elemental Iris Intrepid II XDL, Franklin, USA), and the concentrations of Mn, Cu and Zn by flame atomic absorption spectrometry (FAAS, Perkin Elmer Aanalyst 700, Norwalk, USA). Before the nutrient determination on the ash, the sample was dried overnight to constant mass at 105 °C in a drying oven (Termaks) according to the European standard SFS-EN 12880. A comprehensive review of the standards, analytical methods and instrumentation is given in a previous study (Nurmesniemi et al., 2008).

For the determination of the total heavy metal concentrations in the ash, the dried (5 g) sample was decomposed (digested) with a mixture of HCl (3 ml) and HNO3 (9 ml) in a CEM Mars 5 microprocessor controlled microwave oven with CEM HP 500 Teflon vessels (CEM Corp., Matthews, USA) using USEPA method 3051. Except for Hg, the total element concentrations in the ash sample were determined with a Thermo Elemental IRIS Intrepid II XDL Duo inductively coupled plasma optical emission spectrometer (Franklin, USA). The concentration of Hg in the ash sample was determined with a Perkin Elmer Aanalyst 700 cold-vapour atomic absorption spectrometry equipped with a Perkin Elmer FIAS 400 and AS 90plus autosampler. A comprehensive review of the standards, analytical methods and instrumentation is given in a previous study (Nurmesniemi et al., 2008).

3 Results and discussion

According to Table 1, the pH of the wood pellet ash was strongly alkaline (pH 13.3), which means that it has a strong liming effect. An alkaline pH indicates that part of the dissolved metals in the ash occur as basic metal salts, oxides, hydroxides and/or carbonates (Nurmesniemi et al., 2008). Furthermore, according to the electrical conductivity value (58 mS cm-1), which is an index of the total dissolved electrolyte concentration, the leaching solution of the wood pellet ash has a relatively high ionic strength, indicating that part of the dissolved metals occur as dissolved basic metal salts, e.g. oxides and hydroxides. The dry matter content of the wood pellet ash was very high (99.7%). This is a disadvantage and may increase the amount of dust during handling.

The slightly elevated LOI (5.3%; d.w.) and TOC (5.7%, d.w.) values indicate that the ash contains some unburnt organic material due to incomplete combustion of the fuel in the boiler. The easily soluble Ca concentration of 100 g kg^{-1} (d.w.) was ca. 62.5 times higher than the Ca concentration of 1.6 g kg^{-1} (d.w.) in typical coarse-textured mineral soil in Finland The concentrations of easily soluble Mg (16.5 g kg^{-1}; d.w.), P (0.08 g kg^{-1}; d.w.) were correspondingly ca. 82.5 and 8 times higher than the typical value of Mg (0.2 g kg^{-1}; d.w.) and P (0.01 g kg^{-1}; d.w.) in soil.

Table 1 The physical-chemical properties and the easily soluble nutrient concentrations in the wood pellet ash.

Parameter / nutrient	Unit	Wood pellet ash
pH (1:5)	–	13.3
Electrical conductivity (EC)	mS cm-1	58
Dry matter content (105 °C)	%	99.7
Loss on ignition (LOI, 550 °C)	% (d.w.)	5.3
Total organic carbon (TOC)	g kg-1 (d.w.)	57
Neutralizing value (NV)	% (Ca; d.w.)	34
Reactivity value (R)	% (Ca; d.w.)	26
Ca	g kg-1 (d.w.)	100
Mg	g kg-1 (d.w.)	16.5
Na	g kg-1 (d.w.)	5.0
K	g kg-1 (d.w.)	70
S	g kg-1 (d.w.)	6.7
P	g kg-1 (d.w.)	0.08
Mn	mg kg-1 (d.w.)	1370
Cu	mg kg-1 (d.w.)	23
Zn	mg kg-1 (d.w.)	350

The elevated Ca, Mg and P concentrations in the wood pellet ash indicate that it is also a potential agent for soil remediation and for improving soil fertility. It would therefore be ecological beneficial if the wood ash could be returned to the forest ecosystem. The relatively high easily soluble concentration of K (70 g kg^{-1} d.w) in the wood pellet ash, which contributes to improving soil fertility, is also worth noting. This kind of ash is especially recommendable for nitrogen-rich peatlands, which suffering from a shortage of other nutrients. The liming effect (neutralizing value) is one of the most important indicators in evaluating the agricultural value of ash because ash acts as a liming agent in acidic soil. The capacity of a liming agent to neutralize soil acidity depends on its content of soluble and hydrolysable bases such as oxides, hydroxides, carbonates and silicates. Cations such as calcium, magnesium and potassium are the interactive counter-ions.

The acid neutralizing value (NV) of the pellet ash was 34% expressed as Ca equivalents (d.w.), which indicates that only 1.1 tonne of wood pellet ash would be required to replace 1 tonne of a commercial limestone produced by SMA Mineral Ltd, the neutralizing value of which is 38% (Ca equivalents, d.w.). The reactivity value (R) was determined in order to assess the speed and effectiveness of the neutralizing potential of the liming material in the ash. The R/NA ratio indicates that the so called "fast-acting" capacity of the ash is ca. 76.4%. This means that the wood pellet ash has a liming effect and is therefore a potential soil conditioner and a pH buffer.

Table 2 Total heavy metal concentrations (mg kg^{-1}; d.w.) in the wood pellet ash and the current Finnish limit values (mg kg^{-1}; d.w.) for wood-, peat- and biomass- derived ashes used as forest fertilizer (MMM, 2007).

Metal	Wood pellet ash	Limit value (forest fertilizer)
Cd	16	17.5
Cu	160	700
Pb	12	150
Cr	180	300
Zn	640	4500
As	< 3.0	30
Ni	110	150
Hg	< 0.03	1.0

The total heavy metal concentrations in the wood pellet ash (Table 2) are expressed on a dry weight (d.w.) basis. According to Table 2, the total heavy metal concentrations in the wood pellet ash were lower than the current Finnish limit values for the maximal allowable heavy metal concentrations in forest fertilizers. In Finland, the limit values for the heavy metal concentrations for fertilizers used in forestry came into force in March 2007 (MMM, 2007). In this context it is worth noting that we did not determine e.g. the toxicity of the wood pellet ash. This is due to the fact that, according to Finnish legislation (MMM, 2007), information about the toxicity is not necessary when ash is utilized. However, in some cases the competent authority may decide that the toxicity has to be determined before the ash can be utilize. A comprehensive review of the Finnish limit values and legislation concerning the use of materials as forest fertilizers in Finland is given in (MMM, 2007).

The physical and chemical quality of ash varies significantly depending on factors such as the ratio of the fuels burnt, tree species, growing site, climate and tree component (e.g. bark, wood, leaves). Other factors which affect the physical and chemical quality of the ash are size, age of the tree, logging technique, collection and storage, as well as the burning technique such as the combustion temperature and type of boiler (Steenari and Lindqvist, 1997).

4 Relevance of the research

In Finland, the new limit values for maximal allowable heavy metal concentrations (i.e. Cd, Cu, Pb, Cr, Zn, As, Ni and Hg) in forest fertilizers came into force in March 2007. These limit values, as well as the Finnish national waste legislation, are based on the EU directives and regulations. The results indicated that the wood pellet ash originating from the small-scale (100 kW) district heating plant at Kuusamo, Eastern Finland, is a potential forest fertilizer. The total heavy metal concentrations in the wood pellet ash were lower than the current Finnish limit values for the maximal allowable heavy metal concentrations in forest fertilizers.

References

Alakangas E (2001) Wood energy in small and medium scale biomass boilers and stoves. Opet Finland, VTT Energy, April 2001. Available from: www.tekes.fi/opet/, (Accessed on August 2008).

González J, González-Garcia C, Ramido A, González J, Sabio E, Gañan J and Rodriquez A (2004) *Combustion optimisation of biomass residue pellets for domestic heating with a mural boiler*. Biomass and Bioenergy 27 (2): 145–154.

MMM (2007). *Maa- ja metsätalousministeriön asetus 12/07 lannoitevalmisteista* (Helsinki, 13.02.2007; in Finnish).

Nurmesniemi H, Pöykiö R, Kuokkanen T and Rämö J (2008) *Chemical sequential extraction of heavy metals and sulphur in bottom ash and fly ash from a pulp and paper mill complex. Waste Management & Research* 26 (4): 389–399.

Steenari B and Lindqvist O (1997) *Stabilisation of biofuel ashes for recycling to forest soil. Biomass and Bioenergy* 13 (1–2): 39–50.

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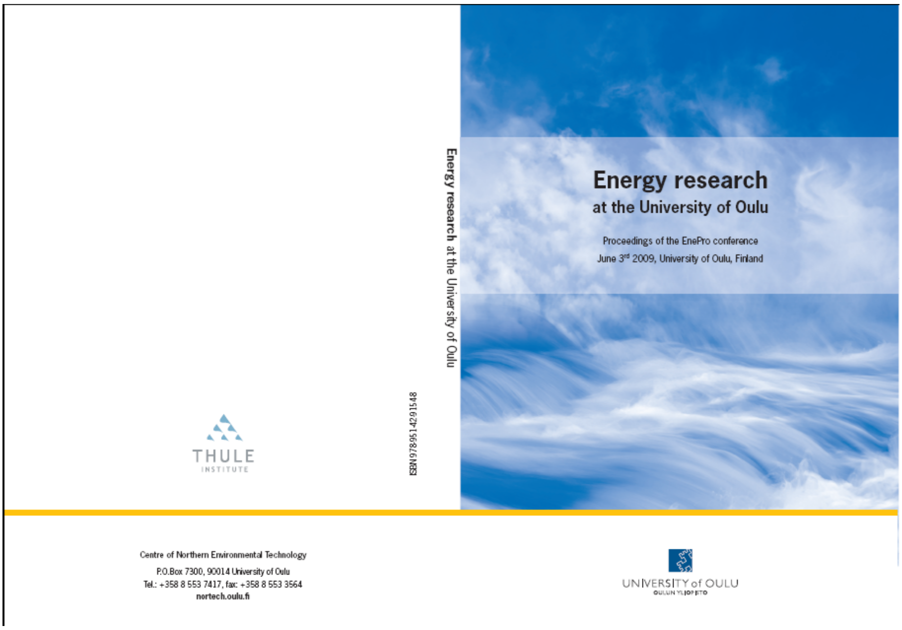

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