GUIDELINE FOR CLASSIFICATION OF ASH FROM SOLID BIOFUELS AND PEAT UTILISED FOR RECYCLING AND FERTILIZING IN FORESTRY AND AGRICULTURE

Nina Haglund and Expert group
Title:
Market harmonisation by dissemination information on new solid biofuel standards and development of ash classification and fuel storage guidelines” (Biostandards project)

Guideline for classification of ash from solid biofuels and peat utilised for recycling and fertilizing in forestry and agriculture

Abstract:
During the review of existing standards (NT TECHN REPORT 584) in the BASREC Bioenergy 2003–2005 project (04215) and in the contacts with numerous solid biofuel professionals from science and industry, needs and ideas for further standards were identified and collected. The need for an ash classification system was identified and Nordic Innovation Centre decided to initiate the development of a Guideline for utilisation of ash from solid biofuels and peat in forestry and agriculture as part of the Nordic Innovation project “Market harmonisation by dissemination on new solid biofuel standards and development of ash classification and storage guidelines (Biostandards).

This Guideline informs about national legislation in Europe on the utilisation of ash from solid biofuels and peat in forestry and agriculture as well as this ash in relation to EU legislation on hazardous waste. Legislation in Denmark, Finland and Sweden is described in detail including limit values for nutrients and minor elements.

A procedure for specification of the ash is defined including suitable methods for sampling and analysis. Ash from solid biofuels as defined in EN14961 “Solid Biofuels – Fuel Specification and Classes” and ash from fuel peat as defined in NT ENVIR 009 “Quality guidelines for fuel peat” are covered. A method for determination of ash reactivity is described. Basic requirements on ash quality declaration are defined and there is a template for ash quality declaration.
Foreword

This is a guideline for classification of ashes from solid biofuels and peat to be published as a Nordtest report. The guideline has been drafted in the project: “Market harmonisation by dissemination information on new solid biofuel standards and development of ash classification and fuel storage guidelines” (Biostandards project - NiCe06180), which is co-ordinated by VTT Technical Research Centre of Finland.

This project is financed by Nordic Innovation Centre, Nordic Council of Ministers, (BASREC renewable energy task force), Finnish Ministry of Employment and the Economy, Swedish Energy Agency and VTT Technical Research Centre of Finland.

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The front page picture is from the RecAsh project and illustrating the spreading of ash.
Introduction

During the review of existing standards (NT TECHN REPORT 584) in the BASREC Bioenergy 2003–2005 project (04215) and in the contacts with numerous solid biofuel professionals from science and industry, needs and ideas for further standards were identified and collected. The need for an ash classification system was identified and Nordic Innovation Centre decided to initiate the development of a Guideline for utilisation of ash from solid biofuels and peat in forestry and agriculture as part of the Nordic Innovation project “Market harmonisation by dissemination on new solid biofuel standards and development of ash classification and storage guidelines (Biostandards project – NICe06180).

Ash from peat is included in the Guideline as peat is often blended with solid biofuels in order to enhance the energy efficiency, which is made possible by this addition. Peat improves the combustion of biofuels by reducing the slagging tendency and corrosion, making it possible to run at a higher steam pressure.

Ash from combustion of solid biofuels and peat can be utilised to contribute to sustainable forest and agriculture management. To facilitate such ash usage a classification system for ash is needed including specification of properties and methods for analysis.

Extraction of forest residues has increased in recent decades. With whole-tree harvesting the export of nutrients and acid buffering substances from the growing site is increased, potentially affecting soil quality and the chemistry of runoff water. There is consequently a long-term need for compensatory fertilisation at many sites in order to maintain the chemical quality in forest streams and lakes. Wood ash contains acid-buffering substances as well as most nutrients which makes it suitable for such compensation. The use of ash can contribute to a decrease in acidification.

With the increasing use of solid biofuels the amount of ash, which has to be taken care of is increasing. Landfill is surrounded by restrictions and is becoming more and more expensive. Utilisation of the ash in forestry and agriculture can serve as part of a solution to this problem.

Ash from solid biofuels has a natural content of heavy metals from the biomass used as fuel. When ash from uncontaminated/pure/unmixed biomass is recycled to the soil the metals contained are the same as would have been there if the biomass had been allowed to biodegrade on the soil. Ash recycling done properly does not increase the levels of heavy metals in forest soils.

Requirements on the ash quality differ depending on local soil conditions. Existing national legislation takes these differences into account.

Ash should not be spread on or near sensitive areas. This guideline does not however include any recommendations on this subject. Information can be found in national legislation and recommendations.
1 Scope

This Guideline informs about national legislation in Europe on the utilisation of ash from solid biofuels and peat in forestry and agriculture as well as this ash in relation to EU legislation on hazardous waste. A procedure for specification of the ash is defined including suitable methods for sampling and analysis. Basic requirements on ash quality declaration are defined and there is an example of a template for ash quality declaration.

This guideline covers ash from solid biofuels as defined in EN14961 “Solid Biofuels – Fuel Specification and Classes” and ash from fuel peat as defined in NT ENVIR 009 “Quality guidelines for fuel peat”.

2 References

These incorporate by dated or undated reference, provisions from other publications. These references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply only when incorporated in the publication by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 14588  
*Solid Biofuels – Terminology, definitions and descriptions*

EN 14961  
*Solid Biofuels – Fuel Specification and Classes*

NT ENVIR 009  
*Quality guidelines for Fuel Peat - Fuel classification and quality assurance, sampling and analysis of properties*

Directive 91/689/EEC  
*Hazardous waste*

<table>
<thead>
<tr>
<th>Sampling method</th>
<th>Name of standard and availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nordtest method for sampling</td>
<td>NT ENVIR 004 Solid waste particulate matter – Sampling, NT standards can be downloaded from <a href="http://www.nordicinnovation.net">www.nordicinnovation.net</a></td>
</tr>
</tbody>
</table>
| CEN method for sampling of waste and associated Technical Reports | EN14889 Characterization of waste materials – Framework for the preparation and application of a sampling plan  
CEN/TR 15310 Part 1–5  
| CEN method for sampling of fertilizer               | EN1482 Sampling of solid fertilizers and liming materials                                         |
| CEN Horizontal draft methods for sampling            | CEN BT Tf151 WICSS599031 Sludge, treated biowaste and soils in the landscape – Sampling for the preparation and application of a sampling plan. This draft standard and Technical reports on sampling can be found on http://www.ecn.nl/horizontal |
| CEN method for sample preparation                    | EN15002 Characterization of waste – Preparation of test portions from the laboratory sample         |
| ISO standard for sample preparation of coal samples  | ISO 13909 Hard coal and coke – Mechanical sampling – Part4 Coal Preparation of test samples        
ISO 18283 Hard coal and coke – Manual sampling
<table>
<thead>
<tr>
<th>Ash property</th>
<th>Standard/Technical specification</th>
</tr>
</thead>
</table>
| Content of major elements (K, Ca, Mg, P) | CEN/TS 15290 Solid Biofuels – Determination of major elements Part B (omit ash procedure)  
CEN/TS 15410 Solid recovered fuels – Method for determination of major elements  
EN13656 Characterization of waste – Microwave assisted digestion with HF, HNO₃ and HCl for subsequent determination of elements in waste |
| Content of minor elements (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, V, Zn) | CEN/TS 15411 Solid recovered fuels – Method for determination of minor elements  
EN13656 Characterization of waste – Microwave assisted digestion with HF, HNO₃ and HCl for subsequent determination of elements in waste |
| Content of boron (B) | EN13656 Characterization of waste – Microwave assisted digestion with HF, HNO₃ and HCl for subsequent determination of elements in waste |
| Content of total chlorine (Cl) | ISO 587 Solid mineral fuels – Determination of chlorine, Eschka method |
| Content of water soluble chlorine (Cl) | CEN/TS 15105 Solid biofuels – Method for determination of water soluble content of chlorine, sodium and potassium  
ISO 11722 Solid mineral fuels – Hard coal – Determination of moisture in the general analysis test sample by drying in nitrogen |
| Content of total moisture | ISO 589 Hard coal – Determination of total moisture |
| Content of moisture in analysis sample | EN14346 Characterization of waste – Calculation of dry matter by determination of dry residue or water content  
EN12048 Solid fertilizers and liming materials – Determination of moisture content  
ISO 11722 Solid mineral fuels – Hard coal – Determination of moisture in the general analysis test sample by drying in nitrogen |
| Content of water soluble phosphorous (P) | CEN/TS 15105 Solid biofuels – Methods for determination of water soluble content of chloride, sodium and potassium  
ICP-OES for determination of phosphorous  
ISO 10390-2007 Soil quality – Determination of pH  
Reactivity | See informative Annex D in this document  
Neutralizing value | EN 12945 Liming materials – Determination of neutralizing value |
| Solubility | CEN/TS 14405 Characterization of waste – Leaching behaviour tests - up-flow percolation test  
EN 12457/3 Characterization of waste – Leaching – Compliance test for leaching of granular waste materials and sludges |
|Loss on ignition LOI| CEN/TS 14775 Solid Biofuels – Method for determination of ash content  
EN15169 Characterization of waste – Determination of loss on ignition in waste, sludge and sediments|
|Content of total organic carbon TOC| EN 13137 Characterisation of waste – Determination of total organic carbon (TOC) in waste, sludges and sediments. Method application A (indirect method).|

* The ash should be ground to a nominal top size of max. 0.25 mm (instead of prescribed 1 mm)
3 Terms, definitions and abbreviations

3.1 ash
residue obtained by combustion of a fuel\[1\]

3.2 ash quality declaration
document dated and signed by the producer/supplier, specifying properties of a defined lot\[1\]

3.3 biofuel
fuel produced directly or indirectly from biomass\[1\]

3.4 biomass
material of biological origin excluding material embedded in geological formations and transformed to fossil\[1\]

3.5 peat
decomposed material which has accumulated in waterlogged conditions\[2\]

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ar</td>
<td>as received</td>
</tr>
<tr>
<td>db</td>
<td>dry basis</td>
</tr>
<tr>
<td>LOI</td>
<td>loss on ignition</td>
</tr>
<tr>
<td>TOC</td>
<td>Content of total organic carbon</td>
</tr>
</tbody>
</table>
4 National legislation in Europe on ash utilisation in forestry and agriculture

The view on ash utilisation in forestry and agriculture varies between the European countries, partly due to different conditions. In forestry, the extraction of logging residues leads to a loss of nitrogen, phosphorous, minor elements and substances with acid-buffering properties. Many countries are hesitant to the extraction of biofuels from forests growing on soils with low calcium content. In Sweden there is a need to compensate for losses of buffering substances. In other countries, the physical and chemical weathering of soil particles together with the atmospheric deposition is sufficient to compensate for the nutrient loss. In a large part of continental Europe the soil is rich in calcium allowing the soil to buffer for the acidifying effect of the biomass removal. At forest sites where the nitrogen load is too high, the loss of nitrogen through biomass removal can even be regarded as beneficial.

There are differences also between the conditions in the Nordic countries. In Sweden and Finland the content of acid-buffering substances in the soil is low. In southern Sweden, acidification of the soil is a problem due to acid precipitation and the extraction of forest residues contributes to acidification of soil and water. Therefore, in Sweden, ash recycling is considered to be an important part of sustainable forestry. Finland, on the other hand, has not been exposed to the same amounts of acid precipitation as Sweden and considers the ash as a fertilizer to be utilised to increase growth of forests growing on peatlands. Thus, in Finland, ash fertilization is considered as a part of sustainable forestry. This approach leads to lower limit values for minor elements in Finland than in Sweden. In Denmark, ash recycling is considered as a way to compensate for the loss of potassium and phosphorous.

In Denmark [4] and Finland [5,6,13] there is national legislation on ash utilisation in forestry and agriculture. In Sweden [7], the Swedish Forest Agency has recommendations on utilisation in forestry. In the other parts of Europe, only Austria [8,9] at present, has a legislation on ash utilisation. In several other countries, there are ongoing discussions on this subject and also research projects. For a short description of national legislation, see informative Annex A. For limit values on nutrients and minor elements see Table 3.

Limit values for minimum content of nutrients and maximum values for the content of minor elements vary from country to country. Requirements on which properties to specify also vary. The properties listed in the template for quality declaration in informative/normative Annex E are mandatory, if required by the national legislation and otherwise voluntary.
## Table 3 – Limit values for minor elements and nutrients in the Nordic countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Denmark</th>
<th>Finland</th>
<th>Finland</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>Agriculture/Forestry</td>
<td>Agriculture</td>
<td>Forestry</td>
<td>Forestry</td>
</tr>
<tr>
<td><strong>Nutrients (minimum)</strong></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>80</td>
<td>60</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>K+P 20</td>
<td>K+P 10</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>K+P 20</td>
<td>K+P 10</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td></td>
<td>1500</td>
<td>4500</td>
<td>7000</td>
</tr>
<tr>
<td><strong>Minor elements (maximum)</strong></td>
<td>mg/kg</td>
<td>mg/kg</td>
<td>mg/kg</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Arsen (As)</td>
<td>25</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Boron (B)</td>
<td></td>
<td>800</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>5/15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,5</td>
<td>17,5</td>
<td>30</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>100</td>
<td>300</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>600</td>
<td>700</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0,8</td>
<td>1,0</td>
<td>1,0</td>
<td>3</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>30/60&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100</td>
<td>150</td>
<td>70</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>120</td>
<td>100</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td></td>
<td></td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>1500</td>
<td>4500</td>
<td>7000</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Straw ash/wood ash

<sup>b</sup> The limit is 30 mg/kg. For values between 30–60 mg/kg there is dosage limit.
5 The ash and EU legislation on hazardous waste

Ashes possible to utilise in forestry and agriculture according to this Guideline are not hazardous waste from a legal point of view, see informative Annex B. Fresh ash may however be corrosive for a short period of time, until chemical maturity has occurred. Because of this, fresh ash should be handled as corrosive and irritant.
6 Ash specification

6.1 General specification principles

Specification of ash includes specification of
— Fuels used for the combustion/conversion;
— Combustion/conversion unit;
— Type of ash and
— Ash properties including sampling procedure and analysis methods used.

6.2 Specification of fuels

This Guideline covers ash from solid biofuels and peat. Biofuels are specified according to the standard EN 14961 Solid Biofuels – Fuel Specification and Classes [2]. Peat is specified according to NT ENVIR 009 Quality Guidelines for fuel peat [3].

6.3 Specification of combustion/conversion unit and type of ash

For guidance on the terminology of ashes and boilers see informative Annex C.

The combustion/conversion unit is specified by choosing from the list below
— grate combustion;
— fluidised bed combustion;
— pulverized fuel combustion;
— gasification and
— other method (e.g. liquefaction).

The type of ash is specified by choosing from the list below:
— bottom ash;
— fly ash;
— APC (air pollution control residue);
— blend or mixture. Types of ash are to be specified.

NOTE: In Finland APC is not allowed to be used as a fertilizer product.

6.4 Sampling for analysis of ash properties

Correct sampling of the ash is essential to achieve a correct determination of properties. See Table 1 for suitable methods. In the Quality Declaration the sampling procedure and the size of the lot has to be defined.

There are at present no specific CEN or ISO methods for sampling of ashes from solid biofuels. As ashes are included in the scope of CEN/TC 292 Characterization of waste methods (EN 13656, EN 14346, EN 14405 and EN 12457/3) developed within this TC can be used as well as the CEN methods for sampling and analysis of solid fertilizers and liming materials (EN 1482, EN 12048 and EN 12945). Within CEN horizontal
methods for sampling of sludge, treated biowaste and soils, test methods are under development by CEN BT TF151.

For sampling the Nordtest method (NT ENVIR 004) is preferred as this is more specific for ashes.

For sample preparation the CEN/TC 292 method is suitable (see Table 1). The ISO method for sample preparation of hard coal (ISO 13903) may also be used. Several test methods require the ash test sample to be ground to a nominal top size of 0.25 mm or below. (See Table 2).

6.5 Specification of ash properties

6.5.1 General recommendations

Analysis should be carried out at least once a year or when conditions are changed.

It is recommended that analysis is carried out by a certified laboratory.

National legislation usually prescribes the analytical method to be used.

6.5.2 Content of nutrients and minor elements

All legislation on ash utilisation prescribes the specification of a number of minor elements. Often the content of some major elements (nutrients) are also required. For determination of the total content of nutrients and minor elements the methods listed in Table 2 are suitable. Some national legislation may however require the extractable content of the elements (which may be lower) instead of the total content.

6.5.3 Content of unburned matter

Sometimes an ash contains unburnt matter, which may make the ash difficult to harden, which is necessary to obtain a spreadable ash. There are several methods used to estimate the content of unburnt matter, none of them ideal. In this Guideline the determination of TOC is recommended as the standard method for measuring the content of unburned carbon, which can be used for an estimation of unburned matter. Loss on ignition, LOI, at 550°C can be used for non wetted ashes giving useful estimation of unburned matter. For wetted ashes the LOI value will however include also chemically bonded water. The property measured shall be reported as such (TOC or LOI) For more information on different methods see Report 951 “What is unburnt carbon” by the Swedish Thermal Engineering research institute [12].

6.5.4 pH

High pH is an indication of high reactivity of the ash. See Annex D

6.5.5 Reactivity

Reactive ash with high pH and high dissolution rates of salts may cause burns to the vegetation, in particular to Sphagnum mosses, which have been found especially sensitive. A method has been developed to estimate the maximum ash dose on forest land avoiding more than a temporary minor colour change of Sphagnum mosses, see informative Annex D.

6.5.6 Other properties

See Table 2 for recommended methods for determination of the content of moisture, soluble phosphorus and soluble chlorine.
7 Ash quality declaration

The ash quality declaration shall be dated and signed and contain at least the following:

— Name of supplier/producer;
— Size of ash lot;
— Fuels used;
— Combustion/conversion unit;
— Type of ash;
— Sampling procedure;
— Mandatory ash properties (depending on legislation) and
— Specification of method for analysis if different from recommended in this Guideline.

In informative/normative Annex E there is an example of a template for quality declaration where mandatory/voluntary properties to declare are listed.
8 Bibliography


[4] BEK Nr 1636 af 13/12/2006 Bekentgørelse om anvendelse af aske fra forgasning og forbrændning af biomasse og biomasseaffald til jordbruksomål, Denmark [Regulation on utilisation of ashes from biomass in agriculture including forestry].


[7] Skogsstyrelsens meddelande 2008:2 ”Rekommendationer vid uttag av avverkningsrester och askåterföring” [Approximately Recommendations on ash recycling to the forest].

[8] Rückführung von Pflanzenaschen auf Böden, Austria [Recycling of plant ashes to the soil].

[9] Richtlinie für die Aufbringung von Asche aus Holzfeuerungsanlagen und landwirtschaftlich genutzte Böden ”Ascherichtlinien 2006”, Amt der Salzburger Landesregierung, Austria [Regulation on the utilisation of wood ash].


[11] SS 187116 Provtagning av restprodukter från förbränningsanläggningar [Sampling of rest products from combustion]


A1. Nordic countries

**Denmark**

Legislation for ash usage in agriculture and forestry. BEK1636 of 22 December 2006. Revision of the BEK has started.

Only ashes from wood and straw are allowed to be utilised. Wood ash is only to be utilised in forestry and straw ash only in agriculture. Mixtures can be used on both types of land.

For limit values of the content of minor elements see table 3. There are different limits for wood ash and straw ash. The limit is 15 mg Cd/kg for wood ash and 5 mg Cd/kg for straw ash or a mixture of wood and straw ash. If the Loss on ignition, LOI, is over 5%, then the $\sum$PAH have to be analyzed. The limit value for $\sum$PAH is 3 mg/kg dry ash (12 mg/kg in the proposed update).

According to the Danish legislation the content of minor elements and potassium shall be determined as the HNO3-soluble content, which is generally lower than the total content. The method prescribed for this determination is the Danish standard DS 259.

Maximum ash dose in agriculture is 5 ton/ha per 5 year-period. In forestry, the maximum dose is 7.5 ton/ha per 100 year-period. The ash dose in agriculture is also limited by cadmium content. Maximum cadmium load is 0.4 – 0.8 g Cd/ha and year (0.8 – 1 g/ha and year in the proposed update) with different values for wood ash and straw ash. The total supply of phosphorus (in agriculture and forestry) shall not exceed 30 kg/ha, year. In the proposed update there is also a limitation of the dose depending on the reactivity of the ash.

The content of minor elements in the soil has to be under certain limit values to allow ash utilisation.

**Finland**

Legislation:

— Fertilizer Product Act 539/2006 (Lannoitevalmistelaki)

— Ministry of Agriculture and Forestry Decree on fertilizer products 12/07 (Maa- ja metsätalousministeriön asetus lannoitevalmisteista)

— Ministry of Agriculture and Forestry Decree on the operations concerning fertilizer products and their supervision 13/07 (Maa- ja metsätalousministeriön asetus lannoitevalmistelusta koskevan toiminnan harjoittamisesta ja sen valvonnasta)

Only wood, peat or agrobiomass ash is allowed as raw material for agroash and forest ash.

Air pollution control (APC) residues are not allowed to be used as fertilizer products. For limit values of the content of minor elements see Table 3.

There are two type names for ash in Finnish national type designation list for fertilizer products.
Agroash

— Ash to be used as such as a fertilizer product
— To be used in agriculture, horticulture, landscaping and forestry
— Minimum content of P+K 2% and at least 8% of Ca

Forest ash

— Ash to be used as such as a fertilizer product
— To be used only in forestry
— Minimum content of P+K 1% and at least 6% of Ca
— Maximum content of Cl 2%

Solubility of inorganic harmful substances in by-products used as fertilizer products as such should be tested in accordance with the Council of State Decree 202/2006 on amending the Council State Decision on landfill sites, and the solubility should be lower than the limits for metals confirming to the above Decision intended for normal waste.

The average maximum load of cadmium due to the use of fertilizer products must not exceed 1.5 grams of cadmium per hectare per year. The maximum load of cadmium due to the use of fertilizer products as used batches and as cycles of use may be:

a) in agriculture and horticulture, no more than six grams per hectare at an interval of four years;

b) in landscaping, 15 grams per hectare at an interval of 10 years; and

c) in forestry, no more than 60 grams per hectare at an interval of 40 years.

Sweden

The Swedish recommendations are The Swedish Forestry Agency’s view of how ash recycling should be done to meet the requirements provided by the authority regulations to the Swedish Forestry Act (SFS 1979:429) and the general rules of consideration in the Swedish Environmental Code (1998:808).

The recommendations for ash usage in forestry from 2001 have recently been updated. Current recommendation document is “Skogsstyrelsens meddelande 2008:2” Rekommendationer vid uttag av avverkningsrester och askåterföring” (only in Swedish). [7]

It is recommended to recycle ash from biofuels after extraction of logging residues as a contribution to sustainable forest management. The utilisation of ash from other fuels is allowed as long as the ash quality complies with the requirements in the recommendations and not contain other harmful substances.

There are minimum requirements on nutrients and maximum limits for content of minor elements, see table 3. Until 2001 there was a limit also on the content of molybdenum (Mo). This was removed because the concentration of molybdenum in ashes was well within the limit value.

There are restrictions on the content of the Cesium isotope Cs 137 in SSI FS 2005.1. The limit is max 10 kBq/kg for spreading on forest land. For agriculture and for reindeer grazing land the limit is 0.5 kBq/kg.

The recommended ash dose is normally 2–3 ton/ha and rotation period. With a dose of 3 ton/ha and a rotation period of 70 years, the maximum cadmium load would be 1.3 g Cd/ha and year.

The ash should be stabilized before spreading on forest land and the ash dose that can be applied as a single dose is determined by the reactivity of the ash, see informative Annex D.
If the needles are not left evenly distributed at the site after clear-cutting, it is recommended to recycle ash when the total amount of tops and branches extracted corresponds to more than half a ton of wood ash during one rotation period. Ash recycling is always recommended when extraction of harvest residues are performed on peatland or in forests in south western Sweden (i.e. soils which have been acidified by deposition).

Norway

There is no specific legislation or recommendations on ash utilisation.

Legislation on mineral fertilizers was issued in 2003.

A2. Countries outside the Nordic countries

Austria

Legislation in Austria see Rückführung von Pflanzenaschen auf Böden, Austria [Recycling of biomass to the soil][8].

In the Salzburg area there is Amt der Salzburger Landesregierung Abt4/Abt16 Richtlinien 2006 "Richtlinien für die Aufbringung von Asche aus Holzfeuungsanlagenauf landwirtschaftlichen genutzte Böden"[9].

Only ash from non-treated wood is allowed.

No “fine particle” type of ash is allowed.

There are limit values for minor elements and if the total of unburnt carbon is above 5%, analysis of PAH and other organic material is required.

Max 2% ash is allowed to mix into a fertilizer. For cadmium the max load is 3 g Cd/ha and year. The double is allowed if there is no ash used the following year.

The maximum ash dose is 2 ton/ha and year on crop land and 1.5 ton on grassland.

Germany

There are no official limits for heavy metals in wood ash. Some federal states have suggested limits but the discussion is still going on. According to the fertilizer law ashes from untreated wood can be recycled to forest land but other legislation (soil protection, forest law) have to be taken into account.

The Baltic States

No legislation or recommendations specifically for the use of ash from biomass.

Research on recycling of wood ash usage in Lithuania.

The Netherlands

No approval yet for utilisation of any ash from biofuels.

Regulation in 2004 on maximum load of sewage sludge and limit values. From this, the maximum load of Cd per year for crop land and grass land can be calculated. Max load for cadmium is 2.5 g Cd/ha, year on crop land and 1.25 g/ha and year on grass land.
Annex B
(Informative)
Classification of ashes according to Directive 91/689/EEC on hazardous waste

The classification of hazardous waste is regulated by the European Hazardous Waste Directive 91/689/EEC. As a result of the directive, the European Waste Catalogue was produced, listing all wastes grouped according to industry, process or waste type. Ash from thermal processes is listed in the catalogue (see extract from the catalogue below) and as such defined as waste.

Table B1 – Classification of ash according to the European Waste Catalogue

<table>
<thead>
<tr>
<th>Number</th>
<th>Description of waste from thermal processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 01</td>
<td>wastes from power stations and other combustions plants</td>
</tr>
<tr>
<td>10 01 01</td>
<td>bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)</td>
</tr>
<tr>
<td>10 01 03</td>
<td>fly ash from peat and untreated wood</td>
</tr>
<tr>
<td></td>
<td>(10 01 04*) oil fly ash and boiler dust</td>
</tr>
<tr>
<td>10 01 05</td>
<td>calcium-based reaction wastes from flue-gas desulphurisation in solid form</td>
</tr>
<tr>
<td>10 01 07</td>
<td>calcium-based reaction wastes from flue-gas desulphurisation in sludge form</td>
</tr>
<tr>
<td></td>
<td>(10 01 16 fly ash from co-incineration containing dangerous substances)</td>
</tr>
<tr>
<td>10 01 17</td>
<td>fly ash from co-incineration other than those mentioned in 10 01 16</td>
</tr>
</tbody>
</table>

* The waste is classified as hazardous

Ash from biofuels suitable for use on forest or farmland belongs to the waste category 10 01 01 or 10 01 03 and is not listed as hazardous. However, a question is whether a biofuel ash containing small amounts of ash from oil should be classified as 10 01 04 and as such hazardous waste. Many boilers need to be co-fired with oil at upstart, at production peaks and sometimes due to insufficient biofuel quality. This Nordic Guideline suggests that the Directive should be interpreted as ash containing less than 1% of oil fly ash and boiler dust should still be considered as 10 01 01 or 10 01 03 due to the relatively small amount of oil in the total fuel mix as well as the negligible impact of the oil ash on the properties of the biofuel ash. However, the ash shall be classified as hazardous wastes if it contains dangerous substances.

Ash from burning vegetative oils, building wastes, sewage sludge, sludge from the paper industry or other vegetative sources, is suggested to be classified as waste from co-incineration and as such included in the category 10 01 17, or if hazardous to 10 01 16. Thus, in order to correctly classify ash from a co-combustion process, it needs to be clarified whether it possesses any of the properties H1 to H14 according to the criteria provided by the directive. That means that ashes from category 10 01 17 can be bioashes suitable for use on forest or farmland if the content of nutrients and impurities meet the demands.

The properties that may render a bioash hazardous are most likely H4 (irritant), H8 (corrosive) or H14 (ecotoxic). For the definitions of H-categories and the terms irritant, corrosive and ecotoxic see the Directive on Hazardous Waste. According to the directive, a waste should be considered as corrosive or irritant if the concentration of substances possessing these properties exceeds 5%. Ash can be irritant and corrosive due to the content of free calcium oxide and, if wetted, calcium hydroxide. In contact with water, calcium oxide in the ash transforms to calcium hydroxide, which later react with acid oxides like SiO₂, rendering the ash less irritant and corrosive. As a consequence the ash should be wetted and left to mature before being spread.
Wetted and matured ash should not be considered hazardous due to irritant and corrosive properties. This is also coherent with the classification of hazardous waste provided by catalogue, in which fly ash belonging to the waste category 10 01 05 or 10 01 07 is not classified as hazardous. This, even though, the ash contains high concentration of calcium oxide and/or hydroxide.

The directive does not provide any criteria for determining whether a waste possesses ecotoxic properties. While waiting for the EC to determine such criteria, the Swedish Thermal Engineering Research Institute and the Swedish Waste Management (stakeholder and trade association in the field of waste management and recycling) recommend using the concentration limit above which a chemical preparation should be labelled ecotoxic, i.e. when the total concentration of substances possessing ecotoxic properties exceeds 2.5%. Using this limit, biofuel ash will not be classified as hazardous waste due to ecotoxic properties. However, there are ongoing discussions about whether a lower limit of 0.25% should be used. If the stricter limit of 0.25% is used, the actual form of zinc in the ash needs to be known. This since bioash often contains more than 0.25% of zinc and zinc in the form of zinc chloride, sulphate or oxide is considered to be ecotoxic. However, preliminary studies and modelling results show that zinc in ash occur mainly in minerals such as Willemite (Zn$_2$SiO$_4$).

As a conclusion, the guideline considers that wetted ash suitable for use as fertilizer on forest or farmland does not possess dangerous properties according to the criteria provided by the directive and should not be classified as hazardous waste. Wetted ash is ash to which enough water has been added to enable chemical reactions to occur.

However, the ash should be treated as corrosive and irritant before the chemical hardening has occurred.
Annex C

(Ainformative)

A guide to the terminology of ashes and combustion method

This guide was originally created for the applied R&D program "Environmentally correct utilisation of ashes" run by the Swedish Thermal Engineering Research Institute (Värme forsk) as a means to share knowledge on combustion residues with all stakeholders. The emphasis is on the actual residues and on their uses, taking into account the variety of fuels, mixed fuels and plant complexity rather than focusing on residues obtained by ashing pure fuels. The database, called Allaska, is a database on properties of ashes and is available on www.askprogrammet.com in both English and Swedish.

In this annex on terminology also ashes from fuels other than solid biofuels and peat are mentioned (such as municipal waste), which does not mean that those are included in this Nordic Guideline.

C1. Background

Bottom ash, fly ash and APC residue (air pollution control residue) are the only three categories used today to describe an ash in the database Allaska.

Bottom ash is the ash extracted from the lowest part of the furnace while fly ash consists of the particles that, because of their small size or their low density, have been carried over by the combustion gases and fall out in various parts of the boiler and the flue gas cleaning system.

Ash is the mineral non-combustible part of a fuel, including impurities such as sand or gravel. In the flue gas cleaning system reagents are injected to remove pollutants. These reagents are e.g. lime for desulphurisation of the flue gases or active carbon to bind dioxins or mercury. The mixture of fly ash and residues from these reagents is called APC residue.

Limiting oneself to these three categories overly simplifies matters, but the information that is available is often not more detailed. Sometimes, it is necessary to be a little more detailed when describing from where the ash material has been extracted. This higher level of description may have been used in a project reporting data.

C2. Grate combustion or fluidized bed combustion

The words boiler and furnace are often used interchangeably, but this is not the same piece of equipment: the furnace is that part of a “boiler” where the fuel is burned and the boiler is that part where the heat of combustion is delivered to a water/steam circuit. The word boiler is often used for the combination of both units.

In a grate furnace, the solid fuel is pushed onto a grate and combustion air is provided from below and through the grate. The fuel is dried, it is carbonised and then burns out on the grate. What is left of the fuel, ash, falls over the edge of the grate and is carried away as bottom ash. The gases produced during carbonisation are burned above the grate.

In a fluidised bed boiler the velocity of the air flow through the bed is high and the fuel hovers in the gas flow. All three processes (drying, carbonizing and burning-out) go on in the same volume. In order to keep the bed hovering at all stages of combustion, one usually uses an additional material, e.g. sand, to make the bed volume large enough. This may not be necessary if the ash content of the fuel is large.

One distinguishes between bubbling fluidised bed (BFB) and circulating fluidised bed (CFB). In a BFB the gas velocity is moderate and the bed stays in place in the furnace. In a CFB, the gas velocity is high enough to carry fuel and bed material out of the furnace. The bed material is separated from the combustion gases in a cyclone downstream and returned to the furnace.

Oversized material which cannot be suspended in the gas flow is extracted from the bottom of the BFB or CFB as bottom ash. One also bleeds out the bed in order to keep the chemistry of the bed material in the correct range. This ash is sometimes called bed ash.
The size of the pieces of fuel fed to a grate furnace is larger than that of those fed to a fluidised bed furnace. In both cases fuel and primary combustion air are fed from different ports. There is a third type of furnace: the pulverised fuel or PF boiler/furnace. It is common for coal fuels but not common for solid biofuels. Here, the fuel is ground to a powder, pre-mixed with air and injected into the furnace. In many PF boilers powder from wood pellets or sawdust is co-fired with coal.

Ash from a grate furnace or a PF furnace consists only of ash from the fuel and whatever impurities came with it. Ash from a fluidised bed furnace consists of both fuel ash and spent bed material.

**C3. Fly ash in the flue gas duct**

Ash that is carried over by the combustion or flue gases will fall out on low points in the ducts or when there are obstacles. First to fall is the coarse fraction and last the finest fraction.

Very often, the heat exchanging surfaces of the boiler are not placed immediately above the furnace or the bed. The design illustrated in Figure C1 for burning biomass is rather common, also for municipal waste incinerators.

The duct from the combustor has been folded before the gas reaches the boiler proper in order to provide for a longer combustion time. Ash falls out at this 180° turn. The ash may be called shaft turn ash or boiler ash.

When the flue gases pass through the boiler, some more ash will fall out: the boiler ash.

After the boiler the flue gases are led to the flue gas cleaning system before leaving through the chimney stack. De-dusting will take place in one of several types of equipment:

- Cyclones, often a battery of cyclones (multi-cyclones) removing particles above 10 µm
- ESP or electrostatic precipitator, where particles are charged in an electric field and captured by the electrodes, removing particles down to 0.1 µm and reduces dust content to 10–50 mg/Nm³
- Baghouse filters, where dust is captured in textile filters or ceramic inserts, removing the fine particles and reducing the dust content to 3–5 mg/Nm³

A material called fly ash may be called cyclone ash, ESP ash or filter ash if one wishes to keep apart the different types of equipment. All three types are seldom used together in one system. However, one type or two types in combination may be used: e.g. ESP only or cyclone and baghouse filter in succession. Occasionally, boiler ash is regarded as part of the fly ash.

![Figure C1 – Sketch of a municipal waste incinerator with grate furnace and de-dusting system.](image)
C4. Desulphurisation etc.

In order to reduce the sulphur concentration, one may inject an absorbent in the flue gases. This may be lime (most often) or sodium hydrogen carbonate (more seldom). Some time is allowed for the finely divided absorbent and the sulphur dioxide in the gases to react before the spent absorbent is collected in a baghouse filter. This residue (APC residue) consists both of spent absorbent and fly ash.

Active carbon may be injected simultaneously in order to clean the gases from e.g. dioxins and mercury.

Please note that desulphurisation and active carbon are usually not used for clean fuels such as woody biomass.

If cleaning the flue gases needs to be pursued further, one can wash them in e.g. scrubbers. Solid ash is captured in the water at the same time as hydrogen chloride or sulphur dioxide. This ash is then extracted as sludge in the water treatment plant. For the time being,

C5. Vertical boiler

The combustion gases travel horizontally in the plant sketched in Figure C1, which design is typical for grate stokers. Boilers (furnaces) for other fuels are often built with a vertical gas flow. The boiler is then designed as a vertical shaft, the combustion gases make a U-turn at the top of the furnace and boiler and exiting at the bottom, below the last heat exchanging surfaces as in Figure C2. Air for combustion is blown in from the bottom of the furnace.

In this design, the evaporator or boiler surrounds the hearth (the fluidised bed) and the other heat absorbing equipment (e.g. super-heaters and economizer, somewhat loosely called “boiler”) is collected as a package in the U-turn at the top and in the downdraft.

In such a design the combustion gases make a U-turn below the boiler. This is a boiler ash, and occasionally it is called a fly ash.

The same black box is used in Figure C2 to represent a CFB and a BFB. Internal details in a CFB, e.g. the cyclone separating bed material that has been carried over, have been omitted from the sketch.

The bottom ash from a fluidised bed boiler is called “bed ash”, sometimes also “bed sand” as its particle size distribution is close to that of sand.

![Figure C2 – Sketch of a furnace and boiler with a vertical flow of the combustion gases, a design typical for fluidized bed units.](image-url)
C6. Pulverised fuel combustion

Burning a finely divided fuel pre-mixed with combustion air is standard for oil furnaces and the large coal power plants, which are built vertically as in Figure C2. The burners replace the chute that is drawn in the figure.

In these furnaces, one obtains a bottom ash and fly ashes. As the sulphur oxides in the combustion gases from coal need to be removed, one would also obtain APC residues.

As burners do not require much space, one can choose to replace a fluidised bed or a grate with burners if there is not enough empty space around the furnace when one increases the capacity of the plant. The ashes that are obtained are those of the horizontal design, Figure 1, if the burners are mounted in the roof or the walls of a grate furnace, or that of a vertical design, if the burners are mounted in the walls of the furnace in Figure C2.

C7. Mixed ashes

In practice, several flows of ash are collected together. In the boiler sketched in Figure C1, one can extract the U-turn ash and the boiler ash together with the bottom ash in order to save on equipment and handling. The bottom ash will then be a mixture of all three types of ash. Alternatively, the boiler ash may be extracted to the same container as the fly ash collected further downstream in the flue gas duct.

Analogously, one may convey the U-turn ash or boiler ash in Figure C2 to the container for the fly ash or to the container for the bottom ash.

It may be difficult to describe the ash more precisely than bottom ash, fly ash or APC residue if the exact arrangement of the ash extraction is not known.

C8. Wet or dry extraction

The bottom ashes are always hot when they leave the furnace. The most common method to extract them from a grate furnace is to quench them in a water bath below the grate. This way one obtains a quick cooling of the ash as well as extinction of glowing embers of imperfectly combusted fuel – avoiding fires when these are exposed to air.

However, there is also equipment for dry extraction of bottom ashes. In this case, the ash is cooled by the combustion air while the combustible residues are burned out. This technical solution is not very common.

Fly ashes are at a lower temperature when they are collected in the flue gas cleaning system or in the boiler (Figure C1). The fire hazard is smaller. The ashes are dry when extracted from ESP or filter, which is a prerequisite for coal fly ashes being of use in cement or concrete.

It is not unusual to wet the fly ashes from other fuels when they are extracted from silos in order to avoid dust formation.
Annex D
(Informative)
Method for estimating ash reactivity

Reactive ash with high pH and from which salts dissolve quickly may cause damage to the vegetation. Studies have shown that Sphagnum mosses are particularly sensitive. To avoid damages on forest floor vegetation, the ash dose may need to be adjusted according to the properties of the ash. Therefore, the Swedish Forest Agency, in collaboration with the University College of Borås, has developed a method to determine the maximum dose that can be applied as a single dose without causing intolerable damages to Sphagnum mosses. In this method, the ash reactivity estimated by measuring the conductivity in water extract of the ash. The maximum dose is determined from the conductivity measurement and set to avoid more than a temporary and minor colour change of Sphagnum mosses after ash treatment. The reactivity test has been developed for use of ash on forest land and does not apply for use on agricultural land. The method is described in the draft version of the Swedish recommendations for ash recycling to forest land.

A very high pH is an indication of high reactivity and can be used for a first screening of ashes. The pH can be measured on the water extract before the filtration in the method described below (filtration is necessary before the conductivity measurement). If the pH is 13,0 or above, the ash is not suitable for spreading on forest land conductivity measurement does not need to be performed.

D1. Scope
This method defines the procedure to estimate the reactivity of ash from biofuels and peat.

D2. Normative references
For sampling the following method shall be used:
NT ENVIR 004 Solid Waste Particulate Matter – Sampling

D3. Principle
A sample of the ash is extracted with distilled water. The extract is then filtered before the conductivity is measured in the solution. The conductivity measure provides an estimate of the easily soluble fraction of ions in the ash and as such also of the reactivity of the ash. The reactivity estimated by the conductivity is then used to determine the recommended maximum single dose of ash that should be applied in order to avoid damage to sensitive species like Sphagnum mosses and lichens.

D4. Apparatus and materials
— Sieve with 4 mm aperture
— Desiccator with desiccant
— 250 ml Erlenmeyer flask
— De-ionized or distilled water
— Munktell nr 3 filter paper (90 g/m², qualitative, fast filtering and wide pores)
— Büchner funnel
— Büchner flask
— Magnetic stirring plate
— Magnetic stir bar with a pivot ring
— Conductivity meter

D5. Procedure

A representative bulk sample is collected according to one of the standards listed in Normative references. From this sample, a sub-sample of at least 500 g is sieved through a sieve with 4 mm aperture. Both fractions are then weighed and the percentage of ash particles above 4 mm is determined. Only ash from the fraction with particles less than 4 mm is used in the following procedure.

If the fraction of particles <4mm diameter represents < 5% of the total mass, then no testing of reactivity is needed and a maximum dose of 3 tonnes ash/ha may be used.

In order to determine dry matter content of the ash, 5 sub-samples of each 50 g are dried at 105°C until no weight loss is observed (approximately 24 hours). The dried ash samples are stored in a desiccator until weighing. The dry matter content for each sample is then calculated as the proportion of the moist sample and the average dry matter content of the five replicates is used in the conversion from wet to dry mass below.

For the extraction, add 25 g (dry mass) of moist ash to three 250 ml Erlenmeyer flasks. The amount of distilled water needed to obtain an ash: water ratio of 1:5 is then added to the flasks. The flasks are sealed and left to stir for 1 hour at room temperature before the solutions are being vacuum filtered. The electrical conductivity is measured in the filtrates which have to be particle free not to disturb the measurements.

D6. Calculation

The average electrical conductivity of the three replicates is calculated and used to determine the recommended maximum dose of ash that should be applied as a single dose.

<table>
<thead>
<tr>
<th>Electric conductivity (mS/m)</th>
<th>Reactivity category</th>
<th>Recommended maximum ash dose on forest land (ton TS/ha,10 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2800</td>
<td>A</td>
<td>2–3</td>
</tr>
<tr>
<td>2800 – 3200</td>
<td>B</td>
<td>1–2</td>
</tr>
<tr>
<td>3200 – 3600</td>
<td>C</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

D7. Ash with more than 50% of particles over 4 mm

If the ash contains more than 50% of particles larger than 4 mm, the recommended ash dose can be increased by one step in the table. For example, if the average conductivity is 3200 mS/m, the maximum recommended ash dose would be 2 ton/ha. However, a dose of up to 3 ton/ha could be applied if more than 50% of the particles are larger than 4 mm.
D8. Test report

The test report shall include at least the following information

— identification of the laboratory and the testing date
— identification of the sample tested
— a reference to this document
— any deviation from the method described
— individual conductivity measures and average value
— percentage by weight of particles >4 mm
— reactivity category
— recommended maximum ash dose on forest land
— calculated maximum ash dose
Annex E
(Informative/Normative)
Example of a template for Ash Quality Declaration

<table>
<thead>
<tr>
<th>ASH QUALITY DECLARATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier Name</td>
</tr>
<tr>
<td>Contact information</td>
</tr>
<tr>
<td>Number of contract</td>
</tr>
<tr>
<td>Amount of lot</td>
</tr>
<tr>
<td>Intended use</td>
</tr>
<tr>
<td>Fuels used</td>
</tr>
<tr>
<td>Combustion/conversion unit</td>
</tr>
<tr>
<td>Type of ash</td>
</tr>
<tr>
<td>Sampling procedure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
</tr>
<tr>
<td>Potassium (K)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
</tr>
<tr>
<td>P soluble</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minor elements content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance</td>
</tr>
<tr>
<td>Arsenic (As)</td>
</tr>
<tr>
<td>Boron (B)</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
</tr>
<tr>
<td>Lead (Pb)</td>
</tr>
<tr>
<td>Vanadium (V)</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other substances/properties</th>
<th>Value</th>
<th>Method for analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine (Cl) soluble</td>
<td>mg/kg db</td>
<td></td>
</tr>
<tr>
<td>Chlorine (Cl) total</td>
<td>mg/kg db</td>
<td></td>
</tr>
<tr>
<td>Cesium (Cs) 137</td>
<td>Bq/kg db</td>
<td></td>
</tr>
<tr>
<td>ΣPAH</td>
<td>mg/kg db</td>
<td></td>
</tr>
<tr>
<td>Moisture content</td>
<td>w-% ar</td>
<td></td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>w-% db</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>w-% db</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactivity</td>
<td>mS/cm</td>
<td></td>
</tr>
<tr>
<td>Neutralising value</td>
<td>w-% Ca0 db</td>
<td></td>
</tr>
</tbody>
</table>

Method for analysis has to be declared if different from methods listed in Tables 1 and 2.
db = dry basis, ar = as received

Signature of authorised person                Place and date
The Nordic Innovation Centre initiates and finances activities that enhance innovation collaboration and develop and maintain a smoothly functioning market in the Nordic region.

The Centre works primarily with small and medium-sized companies (SMEs) in the Nordic countries. Other important partners are those most closely involved with innovation and market surveillance, such as industrial organisations and interest groups, research institutions and public authorities.

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