Perspectives of Ecochar in Europe

Uses and regulatory requirements

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UNIVERSITY & RESEARCH

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Samenvatting NL
Wageningen research heeft een deskstudie uitgevoerd in opdracht van Mavitec naar de gebruiksmogelijkheden van Ecochar, een biochar gemaakt van mest, en de regelgeving hieromtrent in Europa. Momenteel (mei 2018) ondersteunen Europese en nationale wet- en regelgeving het gebruik en handel van Ecochar als bodembemester niet, alleen als afval. Er zijn voorstellen om de wet- en regelgeving aan te passen maar verwacht wordt dat dit nog 2 tot 3 jaar zal duren. Gebaseerd op de analyse van een Ecochar monster gemaakt van varkensmest en een Ecochar monster gemaakt van kalkoenstrooisel wordt geconcludeerd dat Ecochar gezien kan worden als een nutriëntrijke biochar. Als Ecochar voldoet aan de nog vast te stellen kwaliteitseisen dan worden gebruik als bodembemester en industrieel gebruik gezien als potentieel succesvol. Onderzoek naar biochars is tot op heden vooral gericht geweest op biochars gemaakt van planten. Aanvullend onderzoek is wenselijk.

Summary UK
Wageningen Research performed a desk study commissioned by Mavitec about the possible uses and regulations in Europe of Ecochar, a manure based biochar. Currently (May 2018) European and national regulations do not support the use and trade of Ecochar (manure based biochar) other than ‘waste’ but proposals are currently developed and expected to be implemented in 2-3 years. Based on the results of the analyses of pig manure and turkey litter Ecochars it is concluded that Ecochars are characterised as ‘nutrient rich biochars’. If Ecochar fulfils the quality specifications that will be established in future, use as fertilizer or industrial use can become successful. Research of biochars is dominated with biochars from vegetable resources. Further research is advised.

This report can be downloaded for free at https://doi.org/10.18174/452704 or at www.wur.nl/livestock-research (under Wageningen Livestock Research publications).

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Wageningen Livestock Research Report 1113

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Summary

Wageningen Research performed a desk study commissioned by Mavitec about the possible uses in Europe of Ecochar, a manure based biochar. The study was focused on the use as fertiliser, feed additive and industrial aid and the regulatory requirements involved. Two samples of Ecochar (pig and turkey) were analysed by Eurofins Umwelt Umwelt Ost GmbH. Based on this result the pig and turkey Ecochars are characterised as 'nutrient rich biochars' by the proposed criteria of the Joint Research Centre (JRC).

Regulations regarding biochar at European level are not implemented yet, but proposals are currently developed and expected to be implemented in 2-3 years. National regulations are in force in Germany, Austria, Switzerland and Italy, and limited to biochars from vegetable origin only.

Currently (February 2018) European and national regulations do not support the use and trade of Ecochar (manure based biochar) other than 'waste'. Ecochar is produced by gasification and in the Netherlands gasification is designated as a manure processing method; however, Ecochar does not meet regulatory requirements of the Netherlands. Currently a new European optional regulations on fertilisers is being developed. Within this framework biochars from animal by-products are currently studied by Joint Research Centre (JRC) of the European Commission. Proposals of JRC will lead to end – of – waste criterions. When these European regulations are implemented the 'end of waste' status can be achieved for Ecochar by which free trade within EU27 is facilitated. Legislation about specific uses still has to be taken into account.

Possible uses were assessed by current and future regulations and the properties of Ecochar (economics excluded). If Ecochar fulfils the quality specifications that will be established in future, use as fertilizer or industrial use can become successful. For soil amendment, soil remediation, peat replacement, compost/digestate additive bedding material are thought to be 'possibly successful' because of the properties of the Ecochar will not be completely compatible with the needed properties. The use as feed additive is not thought to become common use within short period of time (>5 years). Research of biochars is dominated with biochars from vegetable resources. Further research is recommended about:

- Availability of nutrients of Ecochar to crops to value fertilising properties
- Exploration of the use of Ecochar in industrial processes
- Quality of the flue gasses, emissions of volatile solids, NOX and SOX.
- Resistance of organic carbon of Ecochar to decomposition
- Use of Ecochar as accelerator in composting and digestion

If Mavitec wants a successful introduction of Ecochar in Europe it is important to adopt Ecochar in new regulation by the European Commission. This can be stimulated by providing information to the right persons. It is also recommended to obtain an approved manure processing status in the Netherlands, while at this moment the technique 'gasification' is recognised but the end product does not meet the specifications(<10% organic carbon).

1 Introduction

This research is commissioned by Mavitec and carried out by Wageningen Research Foundation part of Wageningen University & Research. Mavitec is a company specialised in technologies for food recycling, energy from biomass and processing of animal by-products like slaughterhouse waste and manure. Mavitec Green Energy & Coaltec Energy introduce a new way of solving the manure problem in the form of an energy-based environmental solution called gasification. With this system two products are made: syngas and a solid char (Ecochar). The syngas, a mixture of H_2 and CO, is used to produce heat for drying of the input manure and possibly for electricity production. The Ecochar can possibly be used amongst others for fertilisation, bedding material and all a number other of uses we will address later. Mavitec searches for added value for Ecochar other than the use as fertilizer. Mavitec is therefore keen in finding new and innovative uses for Ecochar. These uses may encounter regulatory constraints. Mavitec search advice on these constraints from European (new) regulations.

1.1 Aim

The aim of the project is to explore the chances and drawbacks considering the use of Ecochar within the regulatory framework that prevails within the European Union.

1.2 Method

A desk study in combination with a field visit to the production site and additional chemical analyses of samples of Ecochar were performed. The desk study consist of a literature review, study of relevant regulations, and study of technical details of the charring process as supplied by Mavitec and Coaltec and expert judgement of Wageningen Research.

Physical-chemical analyses were executed, according to the quality assurance and certification of biochar of the European biochar Certificate (EBC)[1]. The goal of the EBC-certificate is to ensure control of biochar production and quality based on well-researched, legally backed-up, economically viable and practically applicable processes. The analyses were conducted also to determine the value giving plant nutrients in the Ecochar like nitrogen phosphorous and potassium (NPK) and possible contaminants in the product. The samples were delivered by the commissioner and analysed by Eurofins Umwelt Ost GmbH[2]. Two samples were analysed: Ecochar from thick fraction of pig slurry, produced in a gasification unit located in America in the Netherlands and Ecochar from turkey litter gasification unit in the USA. In annex 1 the analytical reports are added.

In this report biochar from manure is called Ecochar, and not considered as a product of Mavitec per se.

[1] http://www.european-biochar.org/biochar/media/doc/ebc-guidelines.pdf
[2] https://www.eurofins.de/umwelt/analyse-pakete/untersuchung-von-pflanzenkohle/analysis-of-biochar/

2 Process description

2.1 Introduction to the process

Biochar is a solid material obtained from the carbonisation of biomass and is produced from intentionally heating a biomass feedstock via pyrolysis (without oxygen) or gasification (limited oxygen), typically in an oxygen limited environment, with the goal of creating a stable, carbon-rich product resistant to degradation. Either ash or char is left behind after gasification, but the maximum amount of char derived from gasification is smaller than what can be produced with pyrolysis.

Biochar is actually a spectrum of materials with certain characteristics, depending on how it is produced, and the feedstock that is used. Various agricultural waste products can be converted into biochar including wood, crop waste, and animal manure. The choice of feedstock significantly impacts the characteristics of the biochar product and its uses. Specific production parameters (including temperature, residence time, rate of temperature increase, pre- and post-processing) also affect the resulting specific characteristics and quality of the biochar. Mavitec foresees the following uses of their Ecochar (a biochar):

- Soil remediation
- Bedding material
- Feed additive
- Soil amendment/fertiliser
- Filterbed (water filtration)
- Replacement of peat
- Additive to compost/sewage sludge, accelerator of composting/sewage treatment processes
- Capture of methane by dairy cattle

The production parameters can impact amongst others the nutrient availability to crops, the physical and chemical properties of the biochar, and the amount of stable carbon sequestered. Depending on the production parameters, more than 50% of the organic material's carbon may be sequestered in a stable form in the biochar.

The idea behind biomass gasification is that biomass is heated with limited oxygen. This produces a different composition of hot gases, which the International Energy Agency and many others call 'producer gas' and which can then be cleaned of different pollutants and tars. The cleaned up gas is called 'syngas'. Syngas, unlike the dirtier producer gas, can be burned to power not just steam turbines, but also gas turbines, Combined Cycle power plants (i.e. ones combining a gas turbine and a steam turbine to increase efficiency), or gas engines. If the producer gas is not cleaned then it can be used as fuel for a boiler (less efficient) that provides steam for a turbine or, otherwise, for providing heat only.

2.2 Gasification

In this study, the terms 'pyrolysis' and 'gasification' are used interchangeably, as a sharp discrimination between both processes cannot be made. In principle, pyrolysis is gasification without or strongly reduced oxygen supply at a lower temperature and gasification is pyrolysis with a limited oxygen supply at a higher temperature (Figure 2.1). We will use the name 'syngas' for the producer gas that is burned in the thermal oxidizer after the gasifier, to produce heat for the drying of input manure in the drier and drying zone of the gasifier.

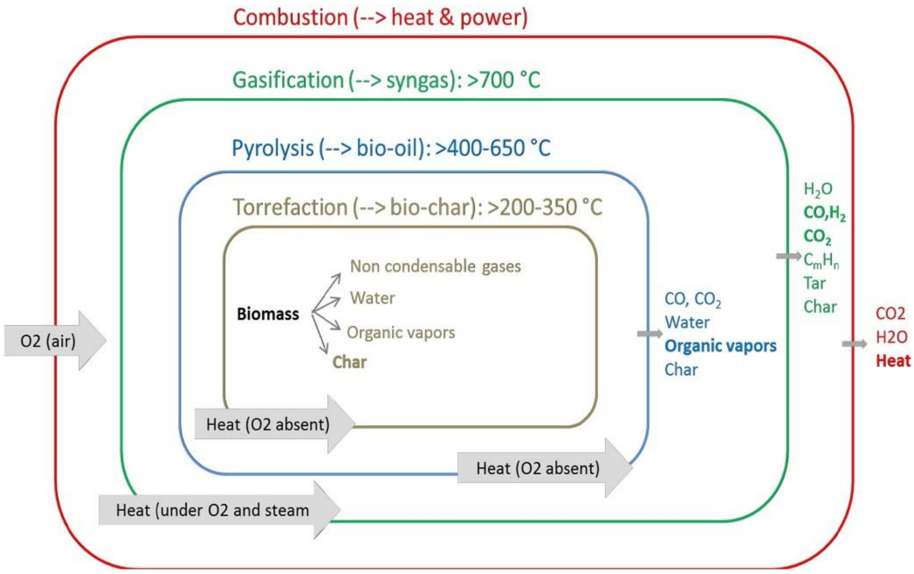

Figure 2.1 *Comparison of Combustion, Gasification, Pyrolysis and Torrefaction; with increasing temperature and oxygen supply, thermochemical conversions shift from torrefaction and pyrolysis to gasification and combustion (Matsakas 2017).*

In Figure 2.1 the major differences between combustion, gasification, pyrolysis, and torrefaction are illustrated in terms of operating conditions and conversion products. The choice for a technique depends fully of the desired endproduct(s). Gasification, pyrolysis, and torrefaction are all performed in the absence of oxygen or with significantly less oxygen (e.g. 1%) than what is required for complete combustion. The operating conditions (e.g., temperature, heating rate, residence time and oxygen supply) and the yield of products (gas, oil/condensables, and char) varies between these three processes. The fast heating rates and moderate temperatures of pyrolysis favour the generation of liquid products. The low temperatures and long residence times of torrefaction primarily yield chars, and the high temperatures and heating rates of gasification mainly generate gas products (condensable and non-condensable gases). Gasification, pyrolysis, and torrefaction cannot be defined as completely separated processes because, for instance, pyrolysis can be considered as an incomplete gasification process and torrefaction as an initial stage of gasification and pyrolysis.

In gasification, partial oxidation can be performed using air, oxygen, steam, carbon dioxide, or a mixture of these as gasifier agents. The gas product (syngas) is a mixture of carbon monoxide, hydrogen, carbon dioxide, methane, and other low-molecular-weight hydrocarbons. It also contains a number of undesired components such as particulate matter, tar, alkali metals, chlorine, and sulphide.

Flue gases from syngas combustion may contain particulate matter, acidic gases (e.g., nitrogen oxides and hydrogen chloride), and organic pollutants such as dioxins. In addition, the final process residues with potential leachability of heavy metals and organic pollutants represent a major environmental concern.

2.3 Mavitec Coaltec gasification process

Mavitec defines 'Ecochar' as biochar, produced by gasification of pre-dried animal manure with or without bedding material, with a typical pH-value of the Ecochar between 9 and 11.
The input capacity of the MAVITEC standard gasification unit is up to 2.25 ton/hr of pre-dried solid manure (based on approx. 25% moisture content), output Ecochar up to 600 kg/hr (≈ 35 % of input on DM basis). Source: MAVITEC

According to Coaltec (McGolden, 2017) for manure gasification, typical process temperatures in the reaction zone range between 650 and 750° C and the residence time of biomass in the reaction zone is between 10 and 20 minutes.
Operators can control the charring process by adapting the residence time, the air flow (including oxygen supply) and the amount of water added in the cooling area. All settings result in a certain quality and quantity of the products (syngas and Ecochar). In annex 2 the control panel of the gasification unit is shown.

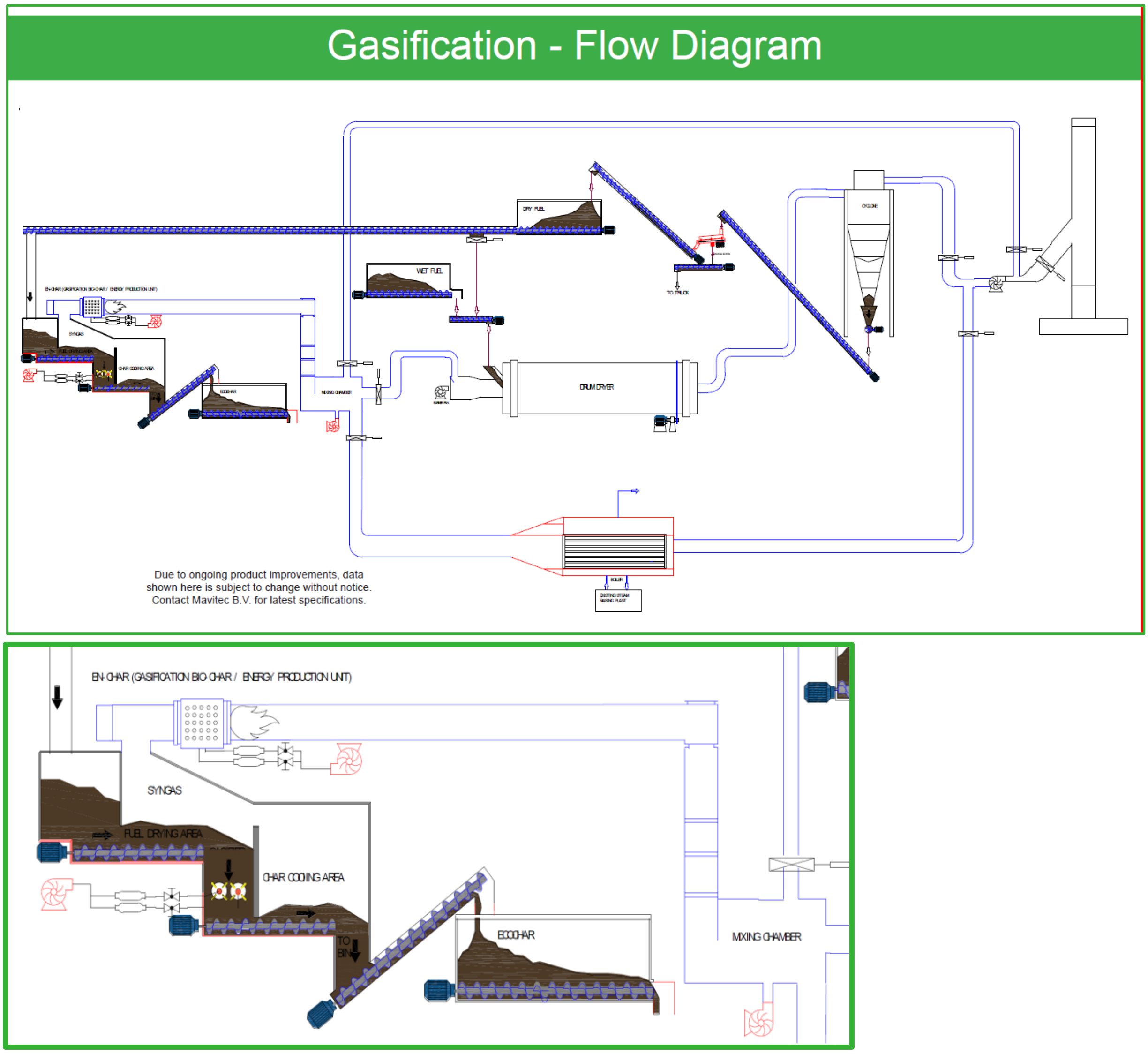

Figure 2.2 *Detail of the Gasification Flow Diagram: from left to right: drying and preheating zone, gasification zone and cooling zone. (Source: MAVITEC).*

The syngas is combusted in a Thermal Oxidizer (Figure 2.3). The design of the Thermal Oxidizer can be adapted to emission regulations in force. Produced hot air is mixed with ambient air to produce the needed temperature. For instance for drying the input or to produce steam for electricity production.

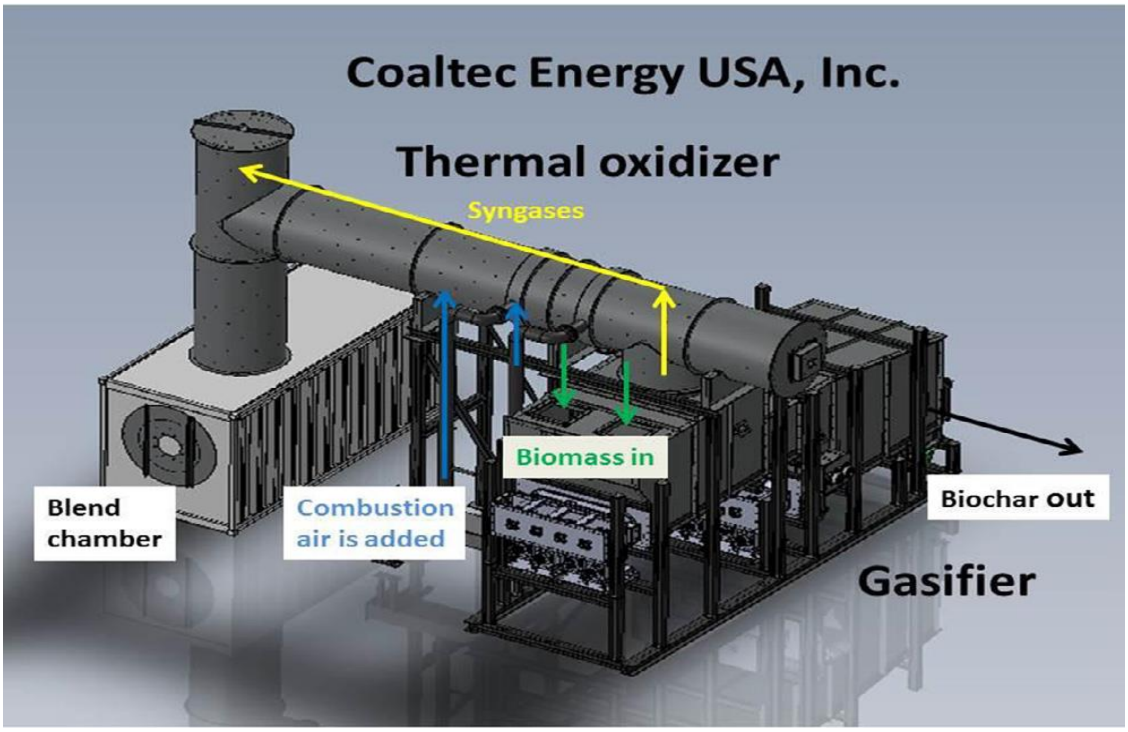

Figure 2.3 *The Thermal oxidizer (syngas burner) between gasifier and mixing chamber. In the mixing chamber, the temperature of the flue gas is reduced by mixing with ambient air.*

2.4 Review of manure processing by gasification

Mavitec requested advice on the opportunities and constraints related to the production of Ecochar from pig slurry and turkey litter. The required dry matter content of the input manure for gasification is approx. 75% dry matter. This roughly corresponds with the dry matter content for fresh turkey manure from deep litter systems in the US (according to Mavitec), but for liquid pig slurry with approx. 8% dry matter, slurry separation and drying of the solid fraction are needed, in order to obtain pig manure with 75% dry matter as input for the gasifier.

The following technologies are used to produce Ecochar from pig slurry (see also figure 2.4):

1. Slurry separation with a sieve belt press, producing a solid and a liquid fraction,
2. Drying of the solid fraction with heat from syngas combustion,
3. Gasification (syngas production) from the solid fraction in the gasification unit,
4. Combustion of the syngas in the thermal oxidizer,
5. Cooling and moistening of the hot Ecochar after gasification,
6. Flue gas treatment to prevent emissions of pollutants,
7. Processing of the liquid fraction into liquid fertilizer (mineral concentrate) and clean water.

These steps will be explained and discussed below. For cattle slurry a comparable process can be applied.

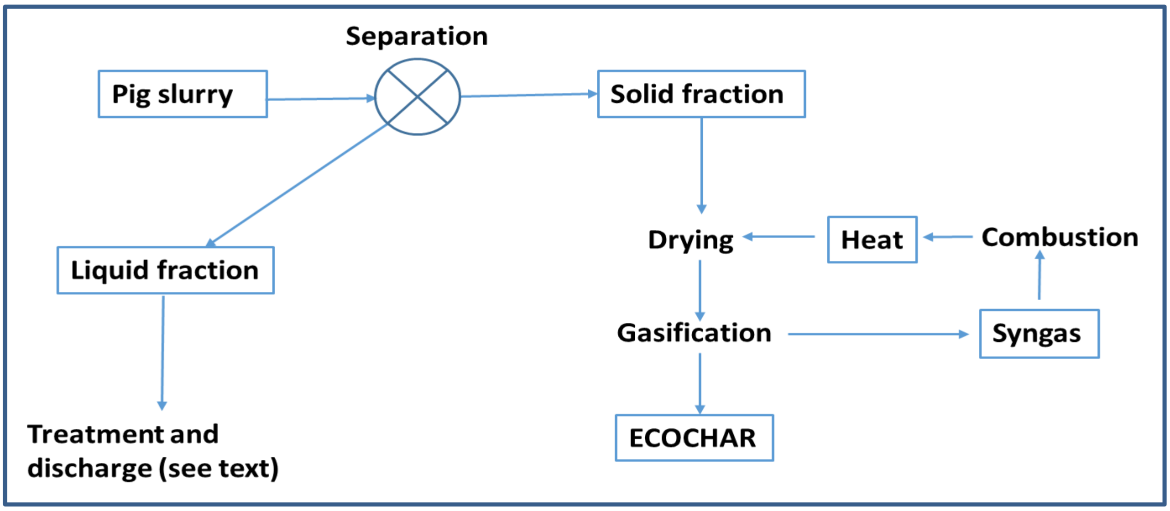

Figure 2.4 *Schematic overview of the production process of Ecochar from pig slurry*

1. Slurry separation

Liquid pig slurry (approx. 8 % dry matter) is mixed with a synthetic flocculant to improve the separation efficiency and is subsequently dewatered by gravity in a dewatering zone, before being squeezed by press rolls between two belts, of which one liquid-permeable belt, separating the liquid from the solid part (Figure 2.5). The solid fraction from the sieve belt press has a dry matter content of approx. 30 %. Slurry separation results in approx. 20 % solid fraction ('manure cake') and 80 % liquid fraction by weight.

Figure 2.5 *Sieve belt press with outgoing solid manure cake with approx. 30 % dry matter (Picture WLR)*

2. Drying of the solid fraction

The solid manure cake is further dried from approx. 30 % dry matter to 75 % dry matter in an indirectly heated drier, using heated oil as a medium for heat transport. The oil is heated with the hot flue gasses from the thermal oxidizer (syngas burner).

3. Gasification of the solid fraction

The solid fraction is gasified (pyrolyzed) during 10 to 20 minutes under low oxygen conditions in a pyrolysis reactor, at a temperature range of 650 - 750°C, producing a combustible syngas and a solid, grainy-powdery material, the so-called Ecochar with approx. 95 % dry matter. The weight reduction of the incoming solid fraction during the gasification process can be 60 to 90 % depending on the ash and moisture contents of the incoming material.

Figure 2.6 *The black powdery bone-dry end product of manure gasification, Ecochar (Picture Mavitec).*

4. Combustion of the syngas

The hot syngas from the gasification unit will contain mainly carbon monoxide, hydrogen and carbon dioxide, but also particulate matter, tar, alkali metals, chlorine and sulphide.
In the thermal oxidizer, the syngas is combusted under high oxygen conditions; the temperature in the thermal oxidizer reaches 1.000° C and more.

5. Cooling and moistening of the hot char

In order to prevent drift and to reduce the risk of dust explosion, the bone-dry ash-like char is cooled down and remoistened by spraying water (addition of 10 - 20 % water by weight). The resulting product is Ecochar.

6. Flue gas treatment

After combustion, the flue gases are cooled down by mixing with ambient air and by subsequent use of the flue gases for heating a boiler with oil that is used for drying the solid manure fraction in an indirect dryer. Before release into the atmosphere, the flue gases are treated in a number of gas scrubbers to remove components that bear an environmental risk.

7. Processing of the liquid fraction

The liquid fraction from the sieve belt press (approx. 2% dry matter) is treated in a DAF-unit (Dissolved Air Flotation) for removal of suspended volatile solids and removal of dissolved salts by membrane filtration (Reverse Osmosis) to produce clean water and a brine, the so-called mineral concentrate that is used as a liquid fertilizer. The clean water is discharged to surface water after removal of the last traces of ammonium nitrogen with an ion exchanger.

2.5 Considerations

Drying capacity

Drying solid fraction of pig manure from 30 to 75% dry matter requires the removal of 300 kg water per ton of incoming solid fraction. On top of that, another estimated 300 kg of water needs to be evaporated in the gasifier. It's uncertain whether the syngas production and syngas quality provide sufficient drying capacity after combustion in the indirect drying system. An energy balance can provide more detailed information. For turkey litter with 75% dry matter, additional drying will not be necessary.

Concentration of non-volatile components
Assuming a phosphate (P_2O_5) content of 4 kg/ton in pig slurry and 18 kg/ton in solid fraction after slurry separation, it can be calculated that the phosphate concentration in the dry Ecochar product will be around 130 kg/ton. This is confirmed by analyses (§3.1). Marketing a fertilizer product from animal manure so high in phosphate will be difficult[3] in the Netherlands, because of the strict phosphate application standards for agricultural land (max. 120 kg P_2O_5/ha/year). Phosphate application standards limits the application rate of Ecochar and thus the application rate of other value giving components. On the other hand high phosphate concentration makes it more efficient to export nutrients. This 30-fold concentration increase will also apply to other non-volatile components, like magnesium, calcium, copper and zinc.

The same applies for Ecochar from turkey litter, with an estimated phosphate content similar to the phosphate content of solid fraction from pig manure with 30% dry matter (phosphate content of turkey litter with 75% dry matter is estimated at 25 kg/ton).

Removal of contaminants after combustion
Volatile solids (tars, hydrocarbons), steam and particulate matter from the gasifier that survive combustion will probably condensate in the dryer or in the scrubbers for flue gas cleaning, producing a contaminated liquid with unknown composition and volume that needs to be disposed of.

Quality of flue gasses
From the estimated composition of solid fraction from pig slurry and the results of char analyses, it can be calculated that a substantial part of the nitrogen and sulphur from the input manure is gasified and ends up in the flue gases after combustion. It is not known whether the gas scrubbers will reduce the loads of NOx and SOx to the required low levels.

Re-moistening and pelletizing
For safety reasons (especially dust explosion) and for reduction of dust emissions during handling, transport and land application, the powdery bone-dry product from gasification needs to be pelletised before being applied to land (Figure 2.7). This might imply a remoistening of the use of additives. Nota bene dimension of the pellets must be adapted to the required applying equipment.

Safety issues
The syngas, containing mainly carbon monoxide, hydrogen, carbon dioxide but also some hydrogen sulphide[4], is extremely toxic and suffocating, requiring strict safety procedures and gas detection in the work space.

[3] The application rate of Ecochar to meet these application standards of the Fertiliser Act in the Netherlands requires a pelletised product.
[4] Low concentrations H_2S one can smell (rotten eggs), but higher – toxic – concentrations one cannot smell.

Figure 2.7 *Land spreading of biochar on a research farm in Finland; this method of application of non-pelletised, dusty material is not accepted in the Netherlands (nor in the EU) (picture from http://www.balticdeal.eu/measure/biochar).*

3 Characterization of Ecochar

3.1 Analytic results Ecochar pig and turkey litter

One sample of Ecochar from pig slurry and one sample of Ecochar from turkey litter were analysed by Eurofins Umwelt Ost GmbH. In table 3.1 a summary of the results is given (annex 1 analytical reports are included). The percentage of phosphorus expressed in P_2O_5 is 12,4 % which is close to the amount of phosphorus (P_2O_5) as theoretically calculated by weight losses during the process (see paragraph 2.5). For the calculation of P to P_2O_5 a factor of 2.29 is used. This is a fixed factor used in European countries.

Dioxins, Polychlorinated biphenyls (PCB) and Polycyclic aromatic hydrocarbons (PAH) in pig Ecochar were measured in concentrations well below the criteria set by the European Biochar Certificate (EBC) (§ 5.1). For pig Ecochar levels of Copper and Zinc are above the criteria of EBC and for turkey Ecochar levels of Chrome and Nickel. The nutrient and metal content of the turkey Ecochar are not in line with expected values based on average content in poultry or turkey litter. By the production of the turkey litter ecochar also woodchips are used as feedstock. This is thought to be the reason why measured values are not in line with the expected values.

Table 3.1 *Analytical results pig Ecochar and turkey Ecochar.*

Parameter	Pig Ecochar	Turkey Ecochar#	Unit	
Bulk density	523	533	kg/m³	as received
Specific surface area (BET)	127.3	105.5	m²/g	as received
Water holding capacity (WHC)	97.3	81.2	% (w/w)	as received
pH in 0.01M CaCl2	9.7	10.6		as received
Moisture	10,6	9.7	% (w/w)	as received
Conductivity	4030	5410	µS/cm	as received
Hydrogen	0.7	< 0,1	% (w/w)	dry basis
Carbon, organic	31.3	27.2	% (w/w)	dry basis
Oxygen	5.7	6,9	% (w/w)	dry basis
H/C ratio (molar)	0.27	0,00		dry basis
O/C ratio (molar)	0.129	0,182		dry basis
Ash content (550°C)	60.4	67.1	% (w/w)	dry basis
Total nitrogen (N)	1.35	0.31	% (w/w)	dry basis
Sulphur (S), total	0.89	0.3	% (w/w)	dry basis
Phosphorus (P)	5.4	3.7	% (w/w)	dry basis
Potassium (K)	3.4	6.3	% (w/w)	dry basis
Copper (Cu)	702	96	g/metric tonne	dry basis
Chrome (Cr)	33	176	g/metric tonne	dry basis
Lead (Pb)	4	2	g/metric tonne	dry basis
Nickel (Ni)	31	117	g/metric tonne	dry basis
Zinc (Zn)	2580	139	g/metric tonne	dry basis

Based on the nutrient and metal levels it is thought that other organic products were mixed with the turkey litter before gasification.

3.2 Ecochar properties

The Ecochar is compared to other biochars or activated chars (see table 3.2) high in in ash content and low in organic carbon. Also characteristics related with this like water holding capacity, specific surface area are lower in the Ecochar than in wood or peat chars. Although the amount of organic carbon is lower, the residual organic carbon in the Ecochar can be characterised as recalcitrant. On the other hand nutrient levels, especially phosphorus and potassium are higher in Ecochar than in wood or peat chars. Joint Research Centre (JRC) distinguishes in their STRUBIAS study (see paragraph 5.1.2) C-rich and nutrient rich biochars. Ecochar is in the vocabulary of JRC a nutrient rich biochar. This has significance for free trade within EU27 (see paragraph 5.1.2).

Table 3.2 *Comparison between COALTEC biochar from cattle manure and activated carbon.*

Physicochemical characteristics of biochar and activated carbon.

Properties	BC	AC
Moisture content (%)	3.95	9.99
Ash content (%)	59.42	14.90
Volatile matter (%)	15.11	14.55
pH_{pzc}	9.8	6.8
%C	29.12	77.10
%H	0.82	1.41
%N	0.82	0.66
BET surface area (m^2/g)	115.5	759.9
Pore size (Å)[a]	58.763	55.789
Pore volume (cm^3/g)[b]	0.074724	0.420963

(Kołodynska et al. 2017).

4 Ecochar uses

The functions indicated by MAVITEC (§2.1) are indeed the functions which are generally attributed to biochars. These functions can be categorised as follows:

a. Fertilising product (soil remediation, soil amendment, fertiliser, peat replacement char, compost (accelerator of composting processes) digestate (accelerator of digestion processes and methane enhancer), bedding material);
b. Feed additives (feed additive, CH_4 capture dairy cattle)
c. Industrial aid (water filtration).

4.1 Fertilising product

Ecochar produced from animal manure is a nutrient rich biochar. Feed additives and industrial aids are currently based on nutrient poor feedstock from vegetable origin such as peat and untreated wood. Therefore the use of Ecochar as a fertilising product is the focus of this study.

A fertilising product serves several uses:

- Source of nutrients:
  - Primary nutrients: nitrogen (N), phosphorus (P), potassium (K)
  - Secondary nutrients: calcium (Ca), magnesium (Mg), sulphur (S), sodium (Na)
  - Micronutrients: boron (B), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), zinc (Zn)
- Source of organic carbon:
  - Function organic soil amendment (soil improver). Maintenance and/or improvement of chemical, physical and biological soil fertility.
  - Function carbon sequestration to combat global warming.
- Liming material:
  - Function: maintenance of soil pH through its acid neutralising value
- Growing media:
  - Replacement of peat
- Biostimulant:
  - Function: stimulation of plant nutrition processes, plants tolerance to abiotic stress and crops quality traits

Ecochar can serve as a source of nutrients, of acid neutralising value (liming material) and of organic C. The organic C is recalcitrant meaning that it is subjected to a very slow biological degradation. This is acknowledged by some as a form of carbon sequestration to combat global warming (CO_2 storage). Ecochar can serve as secondary raw material for the production of a potting soil meaning that it acts as a replacement of peat. Ecochar can possibly serve as a biostimulant[5]. There is no peer reviewed scientific literature to confirm the function as a biostimulant of biochars. This function is therefore not addressed in this report.

A specific function of Ecochar is possibly the uses in soil remediation of a – polluted – soil. There are several forms of soil remediation: removal of a contaminant from the soil and stabilising the

[5] Proposal for definition of biostimulant by the European Commission within the framework of a new fertiliser regulation (There are amendments on this proposal):
A biostimulant means "a product stimulating plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant:
(a) nutrient use efficiency;
(b) tolerance to abiotic stress;
(c) crop quality traits."

contaminant in the soil making the contaminant unavailable for the crop and/or preventing leaching. Biochar can 'fixate' or 'immobilise' pollutants by binding or by increasing soil pH. However the pollutants are not removed. Removal becomes possible as Ecochar is used as a nutrient source but then the availability of the nutrients to the crop must be known of which nitrogen is of prime importance. Next the crop quite often cannot enter the food chain (and thus becomes a waste). Another function is the function of an additive to stimulate the process of composting and an aid to stimulate biogas production. In both cases Ecochar ends up in the resulting compost or digestate and thus becomes a secondary raw material for the production of a fertilising product.

4.1.1 Source of nutrients

In their JRC-study Huygens et al (2017) distinguishes C-rich and nutrient rich pyrolysis materials (see paragraph 5.1.2). Ecochar is a nutrient rich pyrolysis material. It is a source of primary, secondary and micro nutrients. In general the total content of a nutrient has no significance when addressing the fertiliser value. It is the availability of the nutrient for the crop that counts. For nitrogen the speciation over total nitrogen, ammoniacal nitrogen and nitric nitrogen is important. The content of mineral nitrogen (ammoniacal and nitric nitrogen) is directly available for the crop. The difference between total nitrogen and mineral nitrogen is designated as organic nitrogen. Organic nitrogen requires mineralisation to become plant available. Phosphorus availability is depending of the solubility in designated extractants (water, neutral ammonium citrate, alkaline ammonium citrate, citrate, formic acid). In contrast all potassium (total K) is considered crop available. Within this study a conformity assessment as fertiliser has not been conducted nor a study on the nitrogen replacement value. These studies can be a follow up. The availability of the primary nutrients nitrogen, phosphorus and potassium has most impact when valorising Ecochar as a fertilising product in agriculture of horticulture.

Nitrogen

Pyrolysis results in low extractable mineral N concentrations (Huygens et al, 2017). Pyrolysis conditions determine the availability of nitrogen i.e. the concentration of mineral nitrogen and the concentration of organic nitrogen and the ration between these nitrogen forms. Next the stability of the organic nitrogen has to be taken into account as pyrolysis can lead to more complex organic nitrogen compound (more heterocyclic ring structures). Complex organic nitrogen compounds have a lower rate of degradation, are less available to the crop and thus a lower nitrogen fertiliser replacement value. Ehlert and Oenema (2010) tested biochars produced at different temperatures (300-700˚C) and different pyrolysis duration (30-45 minutes). It was found that hot water extractable carbon (HWC) decreased with increasing temperature while pyrolysis duration did not exert a significant effect. Anaerobically mineralized nitrogen (Nmin) declined from 300˚C to 400˚C and followed by an increase up to 700˚C. At 700˚C about 3 to 4% of the total nitrogen content was anaerobically mineralised.

Phosphorus

The availability of P present in pyrolysis materials depends primarily on P-solubility (Huygens et al, 2017). Based on the work of Wang et al (2012) JRC (Huygens et al, 2017) proposed a ratio of 0.4 (see also paragraph 5.1.2).

Oenema et al (2012) tested the availability of phosphorus from biochars of the thick fraction of fattening pig slurry produced at temperatures of 300 to 700˚C after application to soil and incubation soil over prolonged time. At given time steps, soil samples were analysed on available soil phosphorus. The regular triple super phosphate was used as a reference fertiliser. Phosphorus availability was measured by soil testing for phosphorus based on the ammonium lactated – acetic acid extraction[6] (Egnér et al, 1960). Pyrolysis temperature did not exert an effect of soil phosphorus availability. The increase of plant available phosphorus was comparable with triple superphosphate.

[6] This is the P-Al-value used for P recommendations for grassland in the Netherlands.

Potassium
Potassium in biochar is considered to be readily available (Huygens et al, 2017). Thus potassium in Ecochar can fully be taken into account in a nutrient management plan of a farm.

4.1.2 Organic carbon

Recalcitrant organic carbon
Table 3.1 shows that the Ecochars from pig slurry and turkey litter contain respectively 31.3% and 27.2% organic carbon. Their ash contents are high: respectively 60.4% and 67.1%. From the ash content the total percentage of organic matter can be derived: respectively 39.6% and 32.9%. The ratio of organic carbon to total organic matter is respectively 0.79 and 0.83. Stabile organic matter has a ratio of 0.5-0.6. The analyses show that the Ecochars have a ratio and this points on a higher stability of the organic carbon. Organic carbon of Ecochar is most likely more recalcitrant to decomposition.

The stability of organic carbon determines if nitrogen is immobilised by microorganism in the soil. Immobilisation of nitrogen is observed when (pyrolysis) materials with a high labile organic C content are added to the soil (Huygens et al, 2017). So for Ecochar with a relatively high amount of stable organic matter nitrogen is not supposed to be immobilised. Also higher emission of greenhouse gasses have been observed (Maestrine et al, 2015 citied by Huygens et al, 2017).

Recalcitrant organic carbon is determined by the share of energetically stable aromatic ring structures to the total content of organic C. There is a wide interest how to characterise recalcitrant organic carbon by a common, economical and straightforward approach. Huygens et al (2017) followed EBC's approach by assessing elemental rations of H, C and O. It is based on organic C and not total C as pyrolysis materials can contain inorganic carbonates. The proposed criteria of JRC are in line with EBC's criteria for certification (Table 5.1).

Combat greenhouse gas (GHG) emission
Biochar soil amendments are able to reduce N_2O emissions (i.e. emission peaks). Biochar can also reduce CH_4 emissions, particularly in flooded soils, and when N fertilization rates are not too high (Maestrine et al, 2015 citied by Huygens et al, 2017; Kammann et al, 2017). However the effect biochars have on combating greenhouse gas (GHG) emission still causes debates and underlining mechanisms are not well understood (Kamman et al, 2017).

4.1.3 Acid neutralising value

There are numerous articles that addresses the agronomic function of biochars as liming material caused by the acid neutralising value (Dai et al, 2017). During pyrolysis calcium(hydr)oxides are formed which are responsible for the acid neutralising value. Feedstock and pyrolysis conditions determine the value of biochar as a liming material to maintain soil pH. It depends of the composition if a biochar can act as a liming material.

4.2 Soil remediation

Numerous articles addresses the function of biochar as a soil improver and as a remediation agent. Paragraph 4.1 addresses different functions of biochar as an aid for soil remediation. Ecochar can affect the crop availability of pollutants by immobilisation (fixation).

Biochar applied alone and biochar with compost were able to immobilize soil Cu in an artificially polluted soil (probably due to the increase of CEC and pH after). Biochar and compost is recommended to be added together in copper contaminated soils, as this was the only treatment which was able to enhance soil microbial biomass. Thus, it is expected biochar and compost together will improve ecosystems services delivered by soil microbiota (Cardenas-Aguiar et al, 2017). Immobilisation means that the pollutant is not removed from the soil and a continuous soil management is needed.

4.3 Accelerator

Composting
Biochar shows a strong potential for reducing GHG and NH_3 emissions in the composting of wet nutrient rich materials, particularly when composts are not so frequently turned (aerated, i.e. "lazy composting"). Kammann et al, 2017

Digestion
Fagbohungbe et al. 2016 (review) concluded that biochar has the potential to improve anaerobic digestion process by counteracting substrate induced inhibition, improve digestate quality through nutrient retention, contributing to the buffering capacity of the system and create a surface area for the colonization of microbial cell.

4.4 Bedding material

Thick fractions of manure separation are used as bedding material in cattle farm. Biochar as bedding material is proposed by Schmidt (2013) to combat odour. Sheng et al (2014) found that chicken manure enriched with biochar bedding material led to reduced C, N, P, Cu, and Zn losses from the first runoff event. Although this findings, it is not likely that on the short term biochar from animal manure will find a use as bedding materials. Prevention of dust has to be managed. Area of concern is that ecochar as a food additive is not allowed (see 4.2). So consumption of ecochar bedding material by the animals is also not allowed.

4.5 Feed additive

Charcoal has been used as a feed additive over thousands of years (Kammann et al, 2017). Charcoal, a biochar from vegetable origin, has a positive (but not always significant) effects on parameters such as toxin adsorption, digestion, blood values, feed-use efficiency, cell numbers in milk and livestock weight gain (Schmidt et al, 2016; Kammann et al, 2017). Studies on effectiveness of biochar as a feed additive focus on products with designated feedstock of vegetable origin. Within the EU regulation of feed additives only carbon black of vegetable origins are regulated (7.1.3). Biochars from animal manure are not allowed yet (see 5.2).

Methane capture
Prevention of greenhouse gas emission is a topic that has scientific attention. There are publications that points out that emission can be reduced when a biochar is added to compost or as additive to feed (e.g. Agyarko-Mintah et al, 2017). The reduction is attributed to the sorption characteristics of biochar. Agyarko-Mintah et al (2017) also reported a higher nitrogen content when composting chicken litter with biochar. It is feasible that the use of biochar increase the aeration of compost. This increases improves the oxygen content of the compost and thus prevents the forming of methane. This effect can only be accomplished is the biochar has a coarse structure.

4.6 Industrial aid as filterbed

Biochars from vegetable origins such are Norit made from peat are used amongst others as aids in filterbeds. These type of biochars are C-rich and (very) low in nutrients. Well-structured Ecochar might serve as an industrial as filterbed of waste water treatments with similar functions as a (soil) remediator. This use requires an unlocking of the waste water treatment market.

5 Ecochar in relation to national, European and voluntary regulations

In chapter 4 three categories were distinguished:

1. Fertilising product
2. Feed additives
3. Industrial aid (water filtration)

Each category is subjected to specific regulations. Currently[7] the use of biochars as a fertilising product is regulated on national level in some member states of the European Union (EU27) only. Most European countries have not specific regulations for biochar although all countries have regulatory procedures to include biochar as a fertilising product. That means that one can apply for registration as a fertiliser product. Often it is a request for exemption. Member states differ in their definition of fertilising products and requirements for fertilisers. The regulatory procedures thus differ between member states. Example given: In the Netherlands one can apply for registration in Annex Aa of the Implementation Regulation of the Fertiliser Act. Information on this form of application is given by RVO.nl[8].

There is also no European regulation for biochar yet. However a new regulation on a range of fertilising products has been launched on the 17 of March 2016 by the European Commission as part of their package of measures to stimulate the Circular Economy within EU27 (CEO, 2016). This process will possibly result in a European regulation on biochar. Stakeholders however have developed extra-legal voluntary regulation of biochar production and resulting biochar. This chapter highlights national, voluntary and proposed European requirements for biochar as organic soil improver (§ 5.1.1) and gives a state of the art of current developments for biochars serving as a fertilising product within the framework of a new European fertiliser regulation (§ 5.1.2). The specific status of biochars made from animal manure is addressed in § 5.1.3.

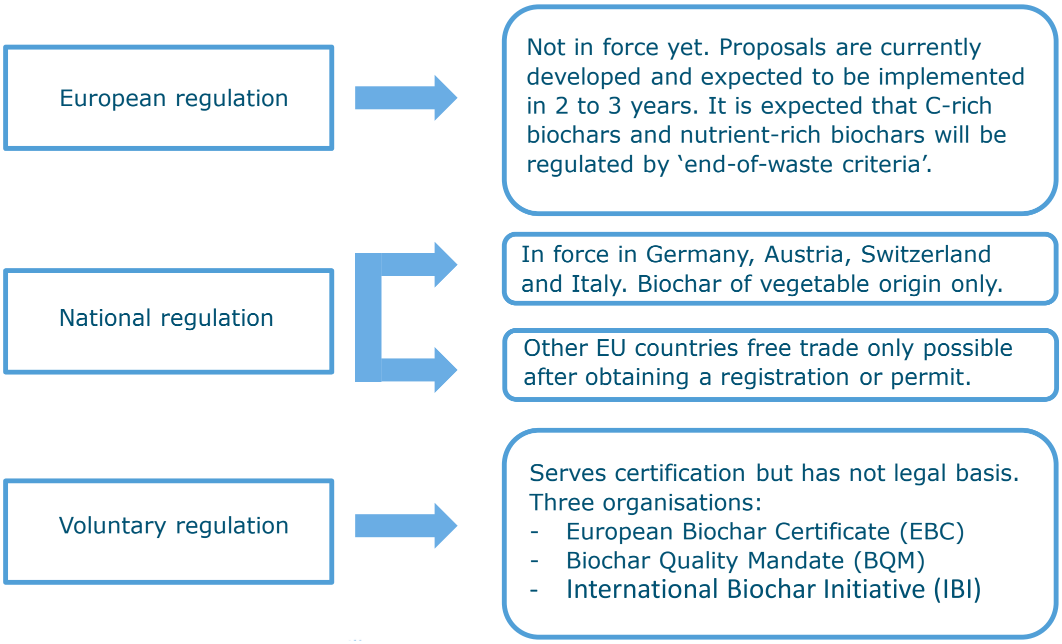

Figure 5.1 *Visualization of regulations on Biochar (In Dutch: Verordening Overbrenging Afvalstoffen (EVOA):Importing and exporting waste materials[9]).*

[7] This study is written in February 2018
[8] In Dutch: https://mijn.rvo.nl/bijlage-aa-van-de-meststoffenwet
[9] https://business.gov.nl/regulation/importing-and-exporting-waste-materials-evoa/

5.1 Regulations of Ecochar as fertilising product

5.1.1 National regulations and voluntary regulations for biochar

There are regulations on free trade of fertilising products. Next there are regulations on the use of fertilising products. In general these are separate regulatory instruments. National regulations on free trade and use of fertilising products differ between European countries (Meyer et al, 2017, Hammond et al, 2016).

There are three systems of voluntary regulation of biochar derived for certification:

1. International Biochar Initiative (IBI[10])
2. European Biochar Certificate (EBC[11]), which distinguishes basic grade and premium grade
3. Biochar Quality Mandate (BQM[12]), which distinguishes standard grade and high grade

IBI is an initiative operating in the USA, EBC operates in EU27 and BQM is a British initiative. IBI has certified in total five biochar plants of which currently there are two plants remaining. BQM has certified nine products of five producers. BQM is owned by the British Biochar Foundation (BBF). As the future of BBF is uncertain, BQM has an uncertain future. EBC had in 2017 certified nine biochar producers in Germany (DE), Austria (AU), Switzerland (CH), Belgium (BE) and Serbia (RS) (in 2015 12). Producers of biochar are certified, not the product itself. The production method is an essential criterion in the certification process. In the new European regulation on fertilising products biochar will be included. Joint Research Centre is conducting currently a study on the criteria which will lead to an end-of-waste-status of biochar (see 5.1.2). The certification criterion of EBC serve as guidelines for the JRC study.

Table 5.1 gives an overview of existing biochar national legislation, voluntary biochar standards and biochar legislation proposals within Europe. DE, AU, CH and IT have product standards but these differ between these countries (Meyer et al, 2017). The same counts for requirements of organic contaminants and pathogens (Table 5.2) and inorganic metals and metalloids (Table 5.3).

Germany (DE), Austria (AU), Switzerland (CH) and Italy (IT) have specific regulations for biochar (Meyer at al., 2017). Other EU countries have not specific regulation for biochar but do have regulatory procedures for free trade of biochar (Hammond et al, 2016, Vereš et al, 2014). In general free trade is not possible for biochars within these countries unless a permit of an exemption has been given. A trader/manufacturer has to apply for a permit or an exemption. As such there is a legal instrument to apply for free trade with a country but apparently it is not used. The Netherlands compared to other EU countries use for national fertilising products a generic regulatory approach meaning that only a few categories of fertilising products are distinguished whilst other EU countries have a detailed regulatory approach meaning that type designation of a product is part of the regulatory process. The generic approach of the Netherlands allows for free trade of biochar if it origins from a product e.g. clean untreated wood or peat (thus charcoal or activated carbon). As (a surplus of) manure is legally a waste (including by-products), free trade of a biochar from manure become possible if the product is included in Annex Aa of the implementation regulation of the Fertiliser Act. For this a request has to be submitted at RVO.nl[13].

In general criterions for free trade of fertilising products are limited to a description of the type of fertilising product (type – designation), criteria for minimum contents of value giving components and tolerances. That is not the case for biochar, national legislation and also voluntary certification often also regulates biological tests (Annex 3), feedstock (positive list) as well as feedstock sustainability requirements (Annex 4) and production methods (Annex 5). Currently national regulations do not

[10] International Biochar Initiative (IBI): http://www.biochar-international.org/
[11] European Biochar Certificate (EBC): http://www.european-biochar.org/en/
[12] Biochar Quality Mandate (BQM): http://www.britishbiocharfoundation.org

[13] https://mijn.rvo.nl/bijlage-aa-van-de-meststoffenwet

allow for category II or III material of Animal byproducts[14] to be used as a feedstock. In exemption in Hungary (HU) Biochar made from food grade pig and poultry bone meal has a permit for free trade[15]. EBC includes animal byproducts as feedstock.

Voluntary product standards for biochar and national regulatory requirements are generally in line, although DE requires a higher dry matter content and IT have additional standards for total ash content, pH value water and salinity (electrical conductivity). Although voluntary regulation are based on more standards for contaminants, their criterions deviate from national regulatory standards for contaminants by setting higher values (Table 5.2 and Table 5.3). Please note that the voluntarily biochar certifications have no legal validity in the EU. The certification standards do also serve other uses of biochar than the use of a fertilising product.

5.1.2 New European fertiliser regulation

On the 17th of March 2016[16] the European Commission (EC) presented a first deliverable of Circular Economy Package with new rules on organic and waste-based fertilisers in the EU (CEP, 2016). This deliverable is a new regulation for fertilising products. The proposal has been amended by the European Parliament (EP) and by the Counsel. On the 24th of October the EP agreed with a series of amendments (282) on December 20th 2017 the ambassadors of the Council agreed with a proposal. This year EC, EP and Council trialogue negotiations has started. It is expected that this will result in a final text for a new regulation in the third quarter of this year. After publication the regulation will come into force after two years (expected 2nd half of 2020).
This new regulation has significance for the free trade of biochar made from animal manure. In short this regulations is as follows.

The new regulation is a form of facultative regulation meaning that it exists next to national regulation. A manufacturer, trader or importer can choose whether EU regulation is followed or national regulation. Member states cannot refuse a product that meets the EU regulation. For free trade this new regulation forms the guideline. Member states can continue to follow their own national regulation on fertilising products but have to respect and implement the new European regulation of fertilising products. A producer, an importer or a trader can decide whether national regulations are followed or the new facultative European fertiliser regulation.

The regulation distinguishes product function categories (PFC) and component material categories (CMC). In 2016 seven (7) PFC are designated (Annex 6) and 11 CMC (Annex 7). However both Council and EP amended the proposal of EC and changes are expected. For biochar these amendments have not a direct effect. These amendments are therefore not discussed in this report.

Both PFC and CMC have to meet criterions for nutrients, acid neutralising value, organic carbon, inorganic contaminants, organic contaminants, pathogens and other not wanted other materials (e.g. plastic and glass in compost). The criterions differ per PFC and CMC.

A PFC may only be produced from designated CMC. For biochar made from animal manure CMC 11 *Certain animal by-products* is important. This CMC will include a table of designated by-products within the scope of EU regulation 1069/2009. DG Sancto will appoint designated by-products. Currently[17] the table is work in progress. EP has proposed animal by-products amongst others animal manure. Council awaits the results of DG Sancto.

[14] REGULATION (EC) No 1069/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)
[15] Terra Humana: https://www.3ragrocarbon.com/ABC
[16] Adopted at 5 December 2015
[17] February 2018

The new regulation of fertilising products has a broad scope. Not only specific annotations are made on the role of producers, traders, importers but also the regulations has to follow the 'New Legislative Framework'[18]. This serves:

- market surveillance rules to protect both consumers and professionals from unsafe products, including those imported from outside the EU;
- the accreditation of conformity assessment bodies;
- CE marking[19];
- Legal framework for industrial products

Due to this 'New Legislative Framework' biochar is expected to be subjected to the REACH regulation (Regulation (EC) 1907/2006[20]). This is a system set up for the Registration, Evaluation, Authorisation and Restriction of Chemicals. REACH registration is needed if a fertilising product is placed on the market in quantities of 1 ton/year or more[21].

To stimulate the circular economy the EC proposed that wastes that meet the requirements of the new regulation on fertilising products will get an 'end-of-waste-status' i.e. regulatory requirements for waste do not apply. This proposal finds general acceptance within Council and EP.

Currently biochar is not included in one of the CMC of the proposal for a new fertiliser regulation. However EC acknowledged the need to set up end-of-waste criteria for biochar (and struvite and ashes of incineration). EC therefore has entrusted Joint Research Centre (JRC) of the European Commission to propose end-of-waste criteria for struvite, biochar and ashes of incineration. For this JRC installed a working group STRUBIAS[22]. JRC started their study in 2016[23]. In May 2017 an interim report (Huygens et al, 2017) was send to STRUBIAS for review. In this report proposals for end-of-waste criteria were given. JRC asked STRUBIAS to comment on these proposals. The comments of the members of STRUBIAS are currently studied. In December 2017 a second report on work in progress on a market study of Huygens & Savey (2017) was forwarded to STRUBIAS with the request to provide additional information. Comments given on the report of May 2017 by STRUBIAS has led to broaden the scope for struvite to recovered phosphate salts and for biochar to pyrolysis materials. In this report for MAVITEC the proposals of JRC of May 2017 are included in Tables 5.1, 5.2 and 5.3 and Annexes 4, 5 and 6. JRC plans to update the report of May 2017 in May 2018.

JRC concludes that inclusion of pyrolysis materials as a CMC in the Revised Fertiliser Regulation enables potential applications for PFC 1 (fertiliser), PFC 3 (soil improver), PFC 4 (growing medium) and PFC 6 (non-microbial plant biostimulant). In their draft JRC concluded that no limitations were needed for pro-processing of the core process of pyrolysis. Product quality is seen as of primordial importance and thus quality standards are needed by not any constrains on the pyrolysis process. Thus JRC chooses for an output regulation and not for an input or throughput regulation. However JRC is proposing a positive list of feedstock's among which animal by-products. This proposal is mainly based on activities of stakeholders pyrolysing animal by-products such as animal bones, leather meal and bone meal. However by proposing categories II and III of the animal by-product regulation (1069/2009), JRC also includes animal manure in their proposal.

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[18] New Legislative Framework
https://ec.europa.eu/growth/single-market/goods/new-legislative-framework_en

[19] CE : Conformité Européenne (French for European Conformity): https://ec.europa.eu/growth/single-market/ce-marking_en

[20] Regulation (ec) no 1907/2006 of the European parliament and of the council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

[21] https://echa.europa.eu/regulations/reach/registration

[22] STRUBIAS is a subgroup of the Fertilisers Working Group
http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=1320
Members are given at: https://ec.europa.eu/growth/content/call-applications-membership-commission-expert-group-recovery-rules-fertilising-products-0_en

[23] http://susproc.jrc.ec.europa.eu/activities/waste/

JRC will elaborate on their proposal. Currently it is not clear yet how the following topics will land in their final report:

- It is proposed to enable a maximum of < 25% of additives delimited to substances/mixtures registered pursuant to REACH (regulation 1907/2006). The discussion is which additives, which criteria to these additives and the need of a REACH registration within.
- JRC follows partial the certification criteria of EBC but also deviates from these criteria. Obviously this causes a debate (with EBC and stakeholders).
- JRC has followed for biochar (and ashes) a risk assessment method to derive proposals for limits for metals and metalloids. These differ between C-rich pyrolysis materials and nutrient-rich pyrolysis materials. However, for struvite JRC followed another risk assessment method (~ what is practically feasible) which was also used for other PFC's and CMC's. The review by members of STRUBIAS was critical on these different approaches in risk assessment for the STRUBIAS products.
- JRC did not propose criteria for copper (Cu) or zinc (Zn). The proposal of the European Commission propose criteria to declare Cu and Zn if contents exceeded 600 mg Cu/kg dry matter of 1500 mg/kg dry matter a declaration is obligatory. This proposal has been debated in the Council. There are memberstates who insists on a maximum value for these micronutrients (300 mg Cu/kg dry matter and 800 mg Zn/kg dry matter). However there is also an option to declare these micronutrients if intentionally added (for organo-mineral fertilisers 0.01% for both Cu and Zn. The trialogue will lead to consensus.
- STRUBIAS materials that will be placed on the market will reach an end-of-waste status and thus become products. Products require in general a registration in REACH although article 2(7)(d)[24] of REACH can exempt materials. Although a final conclusion on REACH registration is not drawn yet, for pyrolysis materials it can be expected that a REACH registration is needed.
- DG Sancto will appoint CMC materials which origins from animal byproducts (EG Regulation 1069/2009). This will result in a table of CMC 11 (Annex 7). It is expected that animal manure will be included in CMC 11. As JRC's positive list has included category 2 and 3 of animal by-products, it is expected that biochar from these categories are included in future regulation of fertilising products. DG Sancto decides on this inclusion.

[24] https://echa.europa.eu/documents/10162/13655/reach_factsheet_on_communication_obligation_en.pdf

Table 5.1 *Overview of existing biochar national legislation, voluntary biochar stands and biochar legislation proposals within Europe, product standards.*

Quality requirements	**unit**	**National legislation**				**Voluntary**					**Proposal EU regulation, JRC-STRUBIAS**	**Pig Ecochar***	**Turkey Ecochar***
		DE	**AT**	**CH**	**IT**	**IBI-BS**	**EBC Basic grade**	**EBC Pre-mium**	**BQM Stan-dard grade**	**BQM High grade**			
Organic Carbon	%	≥80	-	≥50	≥20	≥10	≥50	≥50	≥10	≥10	C-rich pyrolysis material >50% of dry matter	31.3	27.2
Hydrogen-Organic carbon ratio	mol/mol	-	-	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	0.27	0.00
Oxygen/Organic carbon	mol/mol	-	-	-	-	-	<0.4	<0.4	-	-	<0.4	0.27	0.27
Total ash content	%	-	-	-	≤60%	-	-	-	-	-		0.129	0.182
pH value water		-	-	-	4-12	-	-	-	-	-	4-13	9.7	10.6
											Nutrient rich pyrolysis material (P_2O_5+K_2O+CaO+MgO+SO_3)>15% of dry matter and if P_2O_5>7.5%: 2% citric acid soluble P/total P>0.4	40.5 12.3	35.2 8.5
Salinity (electrical conductivity)	mS/cm	-	-	-	≤1000	-	-	-	-	-	Follows phrase 'poor in chloride' if <3%		
Moisture content (of powdery biochar)	%	-	-	≥30	≥20	-	≥30	≥30	≥20	≥20	-		
Physical properties											≤10% particles <100 µm Physical impurities (stones, glass, metals and plastics) greater than 2 mm to < 0.5%		

* Results physical chemical analyses, see paragraph 3.1 and Annex I

Table 5.2 *Overview of existing biochar legislation, voluntary biochar stands and biochar legislation proposals within Europe, organic contaminants and pathogens.*

Quality requirements	**unit**	**National legislation**				**Voluntary**					**Proposal EU regulation, JRC-STRUBIAS**	**Pig Ecochar***	**Turkey Ecochar***
		DE	**AT**	**CH**	**IT**	**IBI-BS**	**EBC Basic grade**	**EBC Pre-mium**	**BQM Stan-dard grade**	**BQM High Grade**			
PAH content (US EPA 16)	mg/kg dm	-	<6	≤4	<6	≤300	<12	<4	<20	<20	<4	0.4	<LOQ
B(a)P toxic equivalency	mg/kg dm	-	-	-	-	≤3	-	-	-	-	-		
PCB	mg/kg dm	-	<0.2	-	<0.5	≤1	<0.2	<0.2	<0.5	<0.5	<0.2 (B)	0.0007	0.0008
PFTs (PFOA and PFOS)	mg/kg dm	≤0.1	<0.1	-	-	-	-	-	-	-			
PCDDs/ Fs toxic equivalents (I-TEQ_{DF})	ng/kg dm	≤30 (≤8)	≤20	≤20	<9	≤17	<20	<20	<20	<20	<20	1.1	0.9
Campylobacter species pluralis		-	ND	-	-	-	-	-	-	-	-		
Escherichia Coli		-	ND	-	-	-	-	-	-	-	-		
Listeria moncytogenes		-	ND	-	-	-	-	-	-	-	-		
Salmonella species pluralis		-	ND	-	-	-	-	-	-	-	-		

ND = Not detectable in 50 g sample.

PCB: sum of 6 congeners PCB 28, 52, 101, 138, 153, 180 mg kg^{-1} (unclear dry matter of fresh matter).

LOQ: Limit of quantification

* Results physical chemical analyses, see paragraph 3.1 and Annex I

Table 5.3 *Overview of existing biochar legislation, voluntary biochar stands and biochar legislation proposals within Europe, inorganic metals and metalloids.*

Quality requirements	**Unit**	**National legislation**				**Voluntary**					**Proposal EU regulation, JRC-STRUBIAS**		**Pig Ecochar***	**Turkey Ecochar***
		DE	**AT**	**CH**	**IT**	**IBI/BS**	**EBC Basic grade**	**EBC Pre-mium**	**BQM Stan-dard grade**	**BQM High Grade**				
		Fertilizer Ordinance	**Fertilizer Ordinance Soil Improvers etc.**	**Fertilizer Ordinance**	**Fertilizer Decree**						**C-rich**	**Nutrient-rich**		
As	mg/kg dm	≤40	≤40	-	-	≤100	<13	<13	≤100	≤10	-	-	1.6	2.6
Ba	mg/kg dm	-	-	-	-	-	-	-	-	-	≤1100	≤4400		
Cd	mg/kg dm	≤1.5	≤3	≤1	≤1.5	≤39	<1.5	<1	≤39	≤3	-	-	0.5	<0.2
Cr	mg/kg dm	-	-	-	-	≤1200	<90	<80	≤100	≤15	-	-	33	176
CrVI	mg/kg dm	≤2	≤2	-	≤0.5	-	-	-	-	-	-	-		
Co	mg/kg dm	-	-	-	-	≤100	-	-	-	-	≤14	≤55		
Cu	mg/kg dm	-	-	≤100	≤230	≤6000	<100	<100	≤1500	≤40	-	-	702	96
Pb	mg/kg dm	≤150	≤100	≤120	≤140	≤300	<150	<120	≤500	≤60	-	-	4	2
Hg	mg/kg dm	≤1	≤1	≤1	≤1.5	≤17	<1	<1	≤17	≤1	-	-	<0.07	<0.07
Mn	mg/kg dm	-	-	-	-	-	-	-	-	≤3500	-	-	1570	829
Mo	mg/kg dm	-	-	-	-	≤75	-	-	≤75	≤10	≤5	≤20		
Ni	mg/kg dm	≤80	≤100	≤30	≤100	≤420	<50	<30	≤600	≤10	-	-	31	117
Sb	mg/kg dm										≤1	≤6		
Se	mg/kg dm	-	-	-	-	≤200	-	-	≤100	≤5	-	-		
Tl	mg/kg dm	≤1	-	-	-	-	-	-	-	-	-	-		
V	mg/kg dm										≤40	≤165		
Zn	mg/kg dm	-	-	≤400	≤500	≤7400	<400	<400	≤2800	≤150	-	-	2580	139

1: Only chemically untreated wood; 2: Biomass of vegetable origin from agriculture and forestry, olive pomace, grape marcs, cereals bran, fruit stones and wood shells, non-treated residues of wood processing; 3: No hazardous municipal solid waste ; 4: Detailed list of permitted feedstock's ; 5: Only biomass feedstock's; 6: vegetable waste, wood waste and bio-waste and animal by-products of category II and III (in line with EBC, 2012).

* Results physical chemical analyses, see paragraph 3.1 and Annex I

In general both analyses of Ecochar of pig slurry and turkey litter do match with by JRC proposed criterions and thus there are perspectives for free trade in EU27. Both analyses show that Ecochar meets the proposals of JRC for a nutrient rich biochar. No restrictions of Copper and Zinc are proposed by JRC, but concentrations of Copper and Zinc are thought to become part of the debate between member states.
Not all parameters proposed by JRC are analysed, there is a discrepancy between the criteria of EBC and JRC.

5.1.3 Biochar from manure and the Nitrates Directive (91/676/EC[25])

The Nitrates Directive aims at controlling pollution and improving water quality. The Nitrates Directive is an integral part of the Water Framework Directive. The regulation was established in 1991. Main focus is prevention of nitrate pollution by leaching and runoff. For this a set of regulatory instruments came into force. Countries which applied for a higher use of nitrogen from animal manure than 170 kg N/ha/year – i.e. applied for a derogation – have agreed with the EC to apply additional regulatory instruments. It is beyond this report to address all these regulatory instruments.

The Nitrates Directive defines fertiliser, chemical fertiliser and livestock manure (article 2e, 2f and 2g of 91/676/EC).

> (e) 'fertilizer`: means any substance containing a nitrogen compound or nitrogen compounds utilized on land to enhance growth of vegetation; it may include livestock manure, the residues from fish farms and sewage sludge;
>
> (f) 'chemical fertilizer`: means any fertilizer which is manufactured by an industrial process;
>
> (g) 'livestock manure`: means waste products excreted by livestock or a mixture of litter and waste products excreted by livestock, even in processed form;

By this set of definitions, particularly by article 2g, a biochar made for animal manure (livestock manure) is defined as livestock manure. This implies that the use of this type of biochar has to meet the regulations for use of livestock manure. In general this means that the biochar may not be applied in quantities larger than 170 kg N/ha (unless the memberstate has a derogation). Next this type of biochar can only applied in specific periods (to prevent nitrate leaching in winter period). Application techniques to prevent ammonia volatilisation also apply.

DG Environment, responsible for the Nitrates Directive, has entrusted several studies on manure processing technologies and the effects of products from animal manure starting a decade ago (Flotats et al, 2011; Foged et al., 2011a, 2011b, 2011c, 2011d.). The aim of the Nitrates Directive and Water Framework Directive (prevention of pollution caused by nitrates) differs from the aims of the new EU regulation on fertilising products (free trade). Please note that the status of a biochar made from animal manure will not changes after implementation of the new EU regulation on fertilising products.

DG Environment, responsible for the Nitrates Directive, acknowledged the need to stimulate the Circular Economy and is currently assessing the criteria which have to be given to nitrogen containing fertilising products made from animal manure. In popular terms: DG Environment is in a process to define the 'end-of-animal-manure-criteria'. For this DG Environment has entrusted JRC a study[26] to develop these criteria. JRC recently started their two-year study after which DG Environment will develop sets of regulatory instruments for nitrogen fertilising products made from animal manure. This study is independent from the study JRC is conducting on the STRUBIAS products. But, it is to be expected that conclusions drawn in the STRUBIAS studies will be used in the study on the 'end-of-animal-manure-criteria'. Please note that the focus will only be on fertilising products from animal manure that can exert similar agronomic and environmental results – meaning have similar nitrogen

[25] COUNCIL DIRECTIVE of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91 / 676 / EEC), http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31991L0676&from=EN

[26] http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=33119&no=3

fertiliser replacement values and not leading to an increased risk on nitrate leaching or nitrate runoff – as regulatory mineral nitrogen fertilisers such as calcium ammonium nitrate (CAN[27]). It will depend processing conditions if a biochar made from animal manure can exert the function of nitrogen fertilising product.

5.1.4 Legal status of Ecochar from manure (situation in the Netherlands)

The legal status of the final product (biochar or Ecochar) from manure gasification can be 'animal manure', 'other organic fertiliser', or 'waste'.

If the legal status is animal manure ('bewerkte dierlijke mest'), the biochar has to be used as fertilizer, according to the Implementation Rules in the Fertilizer Act (in Dutch: 'Uitvoeringsregeling meststoffenwet'). This has consequences for among others the quantities that can be applied on agricultural land (application standards for Nitrogen and Phosphate).

The Fertiliser Act addresses gasification as a method for manure processing and thus is the resulting product of gasification an animal manure. However the condition is that a product of processing of animal manure that the resulting ash contains maximum 10% organic matter (article 70 implementation regulation Fertiliser Act). Ecochar contains more organic matter (Table 3.1). Currently the gasification leads to a product that is not designated as processed manure.

If the legal status is 'other organic fertilizer', the product has to comply with the standards for heavy metals and organic micro-pollutants for 'other organic fertilizers' as described in the Fertilizer Act. The same counts for compost.

Table 5.4 *Maximum levels for heavy metals in 'compost' and 'other organic fertilisers' from national regulation (the Netherlands). The criterions have different units. Heavy metals in compost are given in mg/kg dry matter. Heavy metals in 'other organic fertilisers are based on mg/kg organic matter (loss of ignition). This difference in unit is based on differences in the risk assessment methodology.*

Parameter	Compost, mg/kg dry matter	Other organic fertiliser, mg /kg organic matter
As (Arsenic)	15	10
Cd (Cadmium)	1	0.8
Cr (Chromium)	50	50
Cu (Copper)	90	50
Hg (Mercury)	0.3	0.5
Ni (Nickel)	20	20
Pb (Lead)	100	67
Zn (Zinc)	290	200

Please note that composted animal manure keeps the legal status of 'animal manure' and does not have to comply with the standards for heavy metals for compost or 'other organic fertilisers' and micro-pollutants for 'other organic fertilizers'. The risk of overdosing of heavy metals with composted manure is assumed to be controlled by the strict application standards for phosphate on agricultural land (50-120 kg P_2O_5/ha/year).

If manure is incinerated, it is not considered as biomass but as 'waste' and the process has to comply with the maximum emission standards for waste incineration. Paragraph 5.2 of the 'Activities Decree' (*Activiteitenbesluit*) also applies to manure gasification, unless the flue gasses are treated in such a way, that the emissions from gasification do not exceed the emissions from incineration of natural gas. https://www.infomil.nl/onderwerpen/lucht-water/stookinstallaties/biomassa-0/welk-regime-welke/

[27] In Dutch: kalkammonsalpeter of KAS.

The remaining chars and ashes are, in this case, considered as waste and cannot be used untreated on agricultural land. Because of the waste status the Ecochar can be exported in Europe as waste but not as a fertilising product as other member states do not have regulations for biochar made from an animal byproduct as animal manure. Within the Netherlands use as fertilizer is possible if Ecochar is added to Annex Aa of the implementation regulation of the Fertiliser Act.

5.1.5 The value of biochar as fertilizer in agriculture

CITATION Luesink et al, 2016:
"In the European REFERTIL project and the INTERREG project 'Biochar: climate saving soils', positive effects of biochar in agriculture have not been demonstrated (Compost and Biochar Safety, Economy and EU Law Harmonization Conference). Now that the hype about biochar is over, Austin (2013) and Ruysschaerdt (2013) expect a retail price for large-scale application of 75-100 Euro per ton biochar. Dried and granulated thick fraction of separated pig slurry has a comparable financial yield (Uenk, 2012). It is therefore not profitable to make a product (biochar) from dried manure, using a costly pyrolysis process, which has the same market value as the original product. Certainly when, after the pyrolysis process, a quantity of end product remains that accounts for only 60% of the quantity of incoming product. "

5.2 Regulations of Ecochar as feed additive

Feed additive is mentioned as a possible function of Ecochar. Such biochar is used in animal nutrition for purposes of:

- improving the quality of feed and the quality of food from animal origin,
- to improve the animals' performance and health.

Feed additives may not be put on the market unless authorisation has been given following a scientific evaluation demonstrating that the additive has no harmful effects, on human and animal health and on the environment (https://ec.europa.eu/food/safety/animal-feed/feed-additives).

Carbon black (E153) is an authorized[28] feed additive. Carbon black is a type of biochar made from designated feedstocks many from vegetable origin only. In 2012 the European Food Safety Authority (EFSA) re-evaluated[29] Carbon black on its use as feed additive. It was concluded that use levels vegetable carbon (E 153) containing less than 1.0 µg/kg of residual carcinogenic PAHs expressed as benzo[a]pyrene is not of safety concern.

The name carbon black is also given to biochars from other feedstock such as animal byproducts. However material made from these feedstocks are not regulated as feed additive. Feed additives from animal manure are excluded by EU Regulation 767/2009, article 6, Annex 3, 1[30]. Ecochar therefore cannot be used as a feed additive.

5.3 Regulations of Ecochar as industrial aid

Regulation of Ecochar as an industrial aid depends of its uses. Filterbeds have a broad scope of functions. Within the context of this report, a possible use of Ecochar can be the use of a filterbed in manure processing technologies. Regulation on use as animal manure apply of the spent filterbeds.

[28] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52004XC0225(03)&from=EN

[29] EFSA, 2012. SCIENTIFIC OPINION Scientific Opinion on the re-evaluation of vegetable carbon (E 153) as a food additive. EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS). EFSA Journal 2012;10(4):2592.

[30] Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC (Text with EEA relevance);

6 Conclusions and recommendations

6.1 Conclusions

At het moment of the publication of this report current European and national regulations do not support the use of Ecochar other than 'waste' and use as a fertilizer is not allowed. In the near future European regulation for biochar will be prepared and Ecochar (a product made from animal manure) is expected to be part of this legislation. If the 'end of waste' status is achieved, easier export and trade without the administrative burden of waste export and import becomes possible. If Ecochar meets the proposed quality specifications of the European Joint Research Centre (i.e. the end-of-waste criterions), the use of Ecochar as secondary raw material for fertiliser production or fertilising product becomes possible. Within the proposed criteria of JRC Ecochar will probably be qualified as a nutrient rich biochar. These proposed criteria are still discussed between member states. For ecochar it will be important whether criteria for Copper and Zinc will be implemented as a result of this discussion.
The end of waste status opens a window of opportunities for the use of Ecochar but legislation about specific uses still has to be taken into account (Fertilizers Act etc.). Not all quality criteria of the EBC were acquired (levels of Copper and Zinc in pig ecochar are too high and for turkey ecochar Chrome and Nickel levels are too high).
Research of biochars is dominated with biochars from vegetable resources. Research on biochars from animal manure is scarce. Because properties of biochars from vegetable resources and biochars from manure differ, results of most researches can only give an indication of the possible uses of Ecochars. Possible future uses of Ecochar were assessed by current and expected future regulations and the properties of Ecochar, see table 6.1. Economic feasibility was not taken into account. If Ecochar fulfils the quality specifications that will be established in future, use as fertilizer or industrial use for water filtration might become successful. The other suggested uses are labelled possibly successful because the properties of the Ecochar will not meet the required properties (for instance biochar from vegetable resources suits better). The use as feed additive is not thought to become common use within short period of time (>5 years).

Table 6.1 *Rating of possible uses of Ecochar.*

Category	Use	Total	Properties	Regulation now	Regulation future
Fertilising product	Soil amendment	+/-	+/-	-	+/-
	Fertiliser	+	+	-	+/-
	Peat replacement char	+/-	+/-	-	+/-
	Compost , digestate amendment	+/-	+/-	-	+/-
	Soil remediation,	+/-	+/-	-	+/-
	Bedding material	+/-	+/-	-	+/-
Feed additives	Feed additive	-	?	-	-
Industrial aid	Water filtration	+	+	-	+/-

\+ Successful
+/- Possibly successful
\- Not successful

6.2 Recommendations

This study gives information based on expert judgement and relevant literature sources. Many functions are given to biochars. A stakeholder as the Ithaka Institute gives 55 functions to biochar (http://www.ithaka-institut.org/en/biochar%20products). Obviously the current study cannot assess the robustness of these 55 claims. This requires a more in depth literature study.

Further research is recommended about:

- The quality of the flue gasses, emissions of volatile solids, NOX and SOX.
- Availability of nutrients of Ecochar to crops to value fertilising properties
- Resistance of organic carbon of Ecochar to decomposition
- Exploration of the use of Ecochar in industrial processes
- Use of Ecochar as accelerator in composting and digestion

The discussion in the European Commission about the proposed criteria of JRC-STRUBIAS will be continued. If Mavitec wants to successfully introduce Ecochar in Europe it is recommended to stay informed and emphasize the importance that Ecochar will be adopted in new regulation.
Gasification is an approved method of manure processing in the Netherlands. But the product created with the Mavitec process does not meet fertilizer qualifications (organic carbon should be lower than 10%). Mavitec can try to change regulation about the product to obtain an approved manure processing status.

References

Agyarko-Mintah E., A. Cowie, B. Pal Singh, S. Joseph, L. Van Zwieten, A. Cowie, S. Harden, R. Smillie, 2017. Biochar increases nitrogen retention and lowers greenhouse gas emissions when added to composting poultry litter. Waste Management 61: 138–149.

Cardenas-Aguiar E., G. Gasco, J. Paz-Ferreiro and A. Mendez, 2017. The effect of biochar and compost from urban organic waste on plant biomass and properties of an artificially copper polluted soil. International Biodeterioration & Biodegradation 124: 223-232. http://dx.doi.org/10.1016/j.ibiod.2017.05.014.

CEP, 2016. Circular Economy Package. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009. Brussels 17.3.2016, COM(2016)final. 2016/0084 (COD) + Annexes 1 to 5. http://ec.europa.eu/DocsRoom/documents/15946.

Dai, Zhongmin, Xiaojie Zhang, C. Tang, NiazMuhammad, JianjunWua, Philip C. Brookes, and Jianming Xu, 2017. Potential role of biochars in decreasing soil acidification - A critical review. Science of the Total Environment 581–582:601–611. http://dx.doi.org/10.1016/j.scitotenv.2016.12.169.

Ehlert, P.A.I. and O. Oenema, 2010. Managing phosphorus cycling in agriculture. Phosphate availability of biochars. Biochars from digested fattening pig slurry. BO-12.02-factsheet Nr. 27. Wageningen, NL: Wageningen UR. http://edepot.wur.nl/159677.

Flotats, Xavier, Henning Lyngsø Foged, August Bonmati Blasi, Jordi Palatsi, Albert Magri and Karl Martin Schelde. 2011. Manure processing technologies. Technical Report No. II concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 184 pp.

Foged, Henning Lyngsø, Xavier Flotats, August Bonmati Blasi, Jordi Palatsi, Albert Magri and Karl Martin Schelde. 2011a. Inventory of manure processing activities in Europe. Technical Report No. I concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 138 pp.

Foged, Henning Lyngsø, Xavier Flotats, August Bonmati Blasi, Jordi Palatsi and Albert Magri. 2011b. End and by-products from livestock manure processing - general types, chemical composition, fertilising quality and feasibility for marketing. Technical Report No. III concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 78 pp.

Foged, Henning Lyngsø, Xavier Flotats, August Bonmati Blasi, Karl Martin Schelde, Jordi Palatsi, Albert Magri and Zivko Juznik. 2011c. Assessment of economic feasibility and environmental performance of manure processing technologies. Technical Report No. IV to the European Commission, Directorate-General Environment. Unpublished draft. 130 pp.

Foged, Henning Lyngsø, Xavier Flotats & August Bonmati Blasi. 2011d. Future trends on manure processing activities in Europe. Technical Report No. V concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 34 pp.

Fagbohungbe Michael O., Ben M.J. Herbert, Lois Hurst, Cynthia N. Ibeto, Hong Li, Shams Q. Usmani, Kirk T. Semple; The challenges of anaerobic digestion and the role of biochar in optimizing anaerobic digestion, 5 December 2016, http://dx.doi.org/10.1016/j.wasman.2016.11.028.

Hansen, H.H., I.M.L.D. Storm & A.M. Sell, 2012. Effect of biochar on in vitro rumen methane production Acta Agriculturae Scand. Section A, 62 (4): 305-309. http://dx.doi.org/10.1080/09064702.2013.789548.

Hammond, J., H.P. Schmidt, L. van Schöll, G. Ruysschaert, V. Nelissen, R. Ibarrola, A. O'Toole, S. Shackley & T. van Laer, 2016. The legality of biochar use: regulatory requirements and risk assessment. Biochar in European soils and agriculture. p.227-252. http://hdl.handle.net/1854/LU-7169109.

Huygens Dries, Hans Saveyn, Peter Eder & Luis Delgado Sancho, 2017. STRUBIAS Technical Proposals. Draft nutrient recovery rules for recovered phosphate salts, ash-based materials and pyrolysis materials in view of their possible inclusion as Component Material Categories in the Revised Fertiliser Regulation. Interim Report. Circular Economy and Industrial Leadership Unit Directorate B – Growth and innovation, Joint Research Centre – European Commission.

Huygens Dries & Hans Saveyn, 2017. Draft STRUBIAS Interim Report. Draft market study for recovered phosphate salts, ashbased materials and pyrolysis materials in view of their possible inclusion as Component Material Categories in the Revised Fertiliser Regulation. Interim Report. Circular Economy and Industrial Leadership Unit. Directorate B – Growth and Innovation. Joint Research Centre – European Commmision.

Kammann Claudia, Jim Ippolito, Nikolas Hagemann, Nils Borchard, Maria Luz Cayuela, José M. Estavillo, Teresa Fuertes-Mendizabal, Simon Jeffery, Jürgen Kern , Jeff Novak, Daniel Rasse, Sanna Saarnio, Hans-Peter Schmidt, Kurt Spokas & Nicole Wrage-Mönnig, 2017. Biochar as a tool to reduce the agricultural greenhouse-gas burden – knowns, unknowns and future research needs. Journal of Environmental Engineering and Landscape Management 25 (02): 114-139. https://doi.org/10.3846/16486897.2017.1319375.

Kołodyńska, D., J.Krukowska & P. Thomas, 2017. Comparison of sorption and desorption studies of heavy metals ions from biochar and commercial active carbon. Chemical Engineering Journals 307: 353-363.

Kołodyńska, D., R. Wnętrzak, J.J. Leahy, M.H.B. Hayes, W. Kwapiński and Z. Hubicki, 2012. Kinetic and adsorptive characterization of biochar in metals ions removal. Chemical Engineering Journal 197:295-305.

Luesink et al., Effect afzet mestverwerkingsproducten bij wettelijke status kunstmest of EG-meststof, LEI 2016.

Maestrini, B., P. Nannipieri and S. Abivin, 2015. A meta-analysis on pyrogenic organic matter induced priming effect. GCB Bioenergy 7:577-590.

Matsakas L. et al, Green conversion of municipal solid wastes into fuels and chemicals, 2017, https://doi.org/10.1016/j.ejbt.2017.01.004.

Meyer, S., L. Genesio, I. Vogel, H.P. Schmidt, G. Soja, E. Someus, S. Shackley, F.G.A. Verheijen and B. Glaser, 2017. Biochar standardization and legislation harmonization. Journal of Environmental Engineering and Landscape Management, 25:2, 175-191, DOI: 10.3846/16486897.2016.1254640.

Oenema, O., W. Chardon, P. Ehlert, K. van Dijk, O. Schoumans and W. Rulkens, 2012. Phosphorus fertilisers from by-products and wastes. International Fertiliser Society, Proceedings nr. 717. ISBN 978-0-85310-354-7 (ISSN 1466-1314) http://edepot.wur.nl/265229.

Schmidt, 2013. Novel uses of biochar: a key technology for the planet. Ikhata institute. https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1011&context=biochar.

Schmidt, H. P., C.I. Kammann, A. Gerlach and H. Gerlach, 2016. Der Einsatz von Pflanzenkohle in der Tierfutterung, Ithaka-Journal 95: 364-394. http://www.ithakainstitut.org/ithaka/media/doc/schmidt_pk_fuetterung.pdf.

Sheng, J., A. Adeli, J.P. Brooks, M.R. McLaughlin and J. Read, 2014. Effects of Bedding Materials in Applied Poultry Litter and Immobilizing Agents on Runoff Water, Soil Properties, and Bermudagrass Growth. Journal of Environmental Quality 43 (1): 290-296 DOI: 10.2134/jeq2012.0070.

Vereš J., J. Koloničný & T. Ochodek, 2014. Biochar status under international law and regulatory issues for the practical application. Chemical Enigineering transactions. 37: 799-804. DOI: 10.3303/CET1437134.

Wang, T., M. Camps-Arbestain, M. Hedley and P. Bishop, 2012. Predicting phosphorus bioavailability from high-ash biochars. Plant and Soil 357: 172-187.

Zornoza, R., f. Moreno-Barriga, J.A. Acosta, M.A. Muňoz, A. Faz, 2016. Stability, nutrient availability and hydrophobicity of biochars derived from manure, crop residues, and municipal solid waste for their use as soil amendments. Chemosphere 1444:122-130.

Appendix 1 Analytical reports Eurofins

Eurofins Umwelt Ost GmbH - Lindenstraße 11
Gewerbegebiet Freiberg Ost - D-09627 - Bobritzsch-Hilbersdorf

ZODIAC
gebouwnummer 122
De Elst 1
6708 WD Wageningen
the NETHERLANDS

Title :	**Test report for order 11733815**
Test report number :	**AR-18-FR-001350-01**
Project name :	**Biochar-"European Biochar Certificate"**
Number of samples :	**1**
Sample type :	**biochar**
Sample Taker:	**Client**
Sample reception date :	**2017-12-28**
Sample processing time :	**2017-12-28 - 2018-01-22**

The test results refer solely to the analysed test specimen. Unless the sampling was done by our laboratory or in our sub-order the responsibility for the correctness of the sampling is disclaimed. This test report is only valid with signature and may only be further published completely and unchanged. Extracts or changes require the authorisation of the EUROFINS UMWELT in each individual case.

Our General Terms & Conditions of Sale (GTCS) are applicable, as far as no specific agreements do exist. The GTCS are available on http://www.eurofins.de/umwelt/avb.aspx.

Accredited test laboratory according to DIN EN ISO/IEC 17025 notification under the DAkkS German Accreditation System for Testing. The laboratory is according (D-PL-14081-01-00) accredited.

Attachments

117123065-1
117123065-2

William Homilius	Digitally signed 23.01.2018
Analytical Services Manager	William Homilius
Phone +49 3731 2076516	Prüfleitung

DAkkS Deutsche Akkreditierungsstelle D-PL-14081-01-00

								Description		Pig Char	
				Limit values				Sample number		117123065	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Biochar properties											
Bulk density	FR	JE02	DIN 51705						kg/m³	523	-
specific surface (BET)	SUIB/o		DIN 66137/DIN ISO 9277						m²/g	127,3038	-
true density	SUIB/o		DIN 66137/DIN ISO 9277						g/cm³	2,1061	-
water holding capacity (WHC)	SB99/o		DIN ISO 14238, A						% (w/w)	97,3	-
Moisture	FR	JE02	DIN 51718					0,1	% (w/w)	10,6	-
Ash content (550°C)	FR	JE02	DIN 51719 mod.					0,1	% (w/w)	54,0	60,4
Ash content (815°C)	FR	JE02	DIN 51719					0,1	% (w/w)	52,0	58,2
Volatile Compounds	FR	JE02	DIN 51720					0,2	% (w/w)	11,4	12,8
gross calorific value (Ho,V)	FR	JE02	DIN 51900					200	kJ/kg	10400	11600
net calorific value (Hup)	FR	JE02	DIN 51900					200	kJ/kg	9970	11400
Hydrogen	FR	JE02	DIN 51732					0,1	% (w/w)	0,7	0,7
Carbon	FR	JE02	DIN 51732		> 50		> 50	0,2	% (w/w)	29,6	33,1
Total nitrogen	FR	JE02	DIN 51732					0,05	% (w/w)	1,20	1,35
Oxygen	FR	JE02	DIN 51733, berechnet						% (w/w)	5,1	5,7
Total inorganic carbon (TIC)	FR	JE02	DIN 51726					0,1	% (w/w)	1,6	1,8
carbonate-CO2	FR	JE02	DIN 51726					0,4	% (w/w)	5,8	6,5
carbon (organic)	FR	JE02	berechnet						% (w/w)	28,0	31,3
H/C ratio (molar)	FR	JE02	berechnet		< 0,6		< 0,6			0,27	0,27
H/Corg ratio (molar)	FR	JE02	berechnet		< 0,7		< 0,7			0,29	0,29
O/C ratio (molar)	FR	JE02	berechnet		< 0,4		< 0,4			0,129	0,129
Sulphur (S), total	FR	JE02	DIN 51724-3					0,03	% (w/w)	0,80	0,89
pH in CaCl2	FR	JE02	DIN ISO 10390	10		10				9,7	-
Conductivity	FR		BGK III. C2					5	µS/cm	4030	-
salt content	FR		BGK III. C2					0,005	g/kg	21,3	23,8
salt content	FR		BGK III. C2					0,005	g/l	11,1	12,5
thermogravimetry TGA 950°C by N-Atm.	FR		TGA 701 D4C							see annex	-

								Description		Pig Char	
				Limit values				Sample number		117123065	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Polychlorinated dibenzodioxins/-furans (17 PCDD/F) by GC-HRMS											
2,3,7,8-TetraCDD	GF/o	A026	Internal method					0,18	ng/kg dw	-	< 0,19
1,2,3,7,8-PentaCDD	GF/o	A026	Internal method					0,24	ng/kg dw	-	< 0,25
1,2,3,4,7,8-HexaCDD	GF/o	A026	Internal method					0,48	ng/kg dw	-	< 0,50
1,2,3,6,7,8-HexaCDD	GF/o	A026	Internal method					0,48	ng/kg dw	-	< 0,50
1,2,3,7,8,9-HexaCDD	GF/o	A026	Internal method					0,48	ng/kg dw	-	< 0,50
1,2,3,4,6,7,8-HeptaCDD	GF/o	A026	Internal method					0,54	ng/kg dw	-	< 0,56
OctaCDD	GF/o	A026	Internal method					2,2	ng/kg dw	-	< 2,3
2,3,7,8-TetraCDF	GF/o	A026	Internal method					0,32	ng/kg dw	-	2,0
1,2,3,7,8-PentaCDF	GF/o	A026	Internal method					0,44	ng/kg dw	-	< 0,45
2,3,4,7,8-PentaCDF	GF/o	A026	Internal method					0,44	ng/kg dw	-	0,56
1,2,3,4,7,8-HexaCDF	GF/o	A026	Internal method					0,40	ng/kg dw	-	< 0,41
1,2,3,6,7,8-HexaCDF	GF/o	A026	Internal method					0,40	ng/kg dw	-	< 0,41
1,2,3,7,8,9-HexaCDF	GF/o	A026	Internal method					0,40	ng/kg dw	-	< 0,41
2,3,4,6,7,8-HexaCDF	GF/o	A026	Internal method					0,40	ng/kg dw	-	< 0,41
1,2,3,4,6,7,8-HeptaCDF	GF/o	A026	Internal method					0,52	ng/kg dw	-	< 0,54
1,2,3,4,7,8,9-HeptaCDF	GF/o	A026	Internal method					0,38	ng/kg dw	-	< 0,39
OctaCDF	GF/o	A026	Internal method					3,2	ng/kg dw	-	< 3,3
WHO(2005)-PCDD/F TEQ (lower-bound)	GF/o	A026	Internal method		< 20		< 20		ng/kg dw	-	0,363
WHO(2005)-PCDD/F TEQ (upper-bound)	GF/o	A026	Internal method					0,92	ng/kg dw	-	1,1

				Limit values				Description		Pig Char	
								Sample number		117123065	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Polychlorinated biphenyl (12 WHO PCB) by GC-HRMS											
PCB 77	GF/o	A026	Internal method					3,6	ng/kg dw	-	< 3,7
PCB 81	GF/o	A026	Internal method					0,78	ng/kg dw	-	< 0,81
PCB 105	GF/o	A026	Internal method					7,8	ng/kg dw	-	< 8,1
PCB 114	GF/o	A026	Internal method					0,94	ng/kg dw	-	< 0,97
PCB 118	GF/o	A026	Internal method					28	ng/kg dw	-	43
PCB 123	GF/o	A026	Internal method					0,80	ng/kg dw	-	< 0,83
PCB 126	GF/o	A026	Internal method					1,0	ng/kg dw	-	< 1,1
PCB 156	GF/o	A026	Internal method					4,4	ng/kg dw	-	9,0
PCB 157	GF/o	A026	Internal method					0,90	ng/kg dw	-	< 0,93
PCB 167	GF/o	A026	Internal method					2,2	ng/kg dw	-	4,6
PCB 169	GF/o	A026	Internal method					2,4	ng/kg dw	-	< 2,5
PCB 189	GF/o	A026	Internal method					0,80	ng/kg dw	-	< 0,83
WHO(2005)-PCB TEQ (lower-bound)	GF/o	A026	Internal method						ng/kg dw	-	0,00170
WHO(2005)-PCB TEQ (upper-bound)	GF/o	A026	Internal method					0,17	ng/kg dw	-	0,18

								Description		Pig Char	
				Limit values				Sample number		117123065	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Polychlorinated biphenyl (7 PCB) by GC-HRMS											
PCB 28	GF/o	A026	Internal method					0,082	µg/kg dw	-	< 0,085
PCB 52	GF/o	A026	Internal method					0,061	µg/kg dw	-	< 0,063
PCB 101	GF/o	A026	Internal method					0,098	µg/kg dw	-	0,13
PCB 118	GF/o	A026	Internal method					0,028	µg/kg dw	-	0,043
PCB 138	GF/o	A026	Internal method					0,072	µg/kg dw	-	0,14
PCB 153	GF/o	A026	Internal method					0,12	µg/kg dw	-	0,21
PCB 180	GF/o	A026	Internal method					0,030	µg/kg dw	-	0,057
Total 6 ndl-PCB (lower-bound)	GF/o	A026	Internal method		< 200		< 200		µg/kg dw	-	0,545
Total 6 ndl-PCB (upper-bound)	GF/o	A026	Internal method						µg/kg dw	-	0,693
Total 7 Indicator PCB (lower-bound)	GF/o	A026	Internal method		< 200		< 200		µg/kg dw	-	0,588
Total 7 Indicator PCB (upper-bound)	GF/o	A026	Internal method					0,46	µg/kg dw	-	0,74

Parameter	Lab	Accr.	Method	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	LOQ	Unit	ar	db
								Description		Pig Char	
				Limit values				Sample number		117123065	
Elements from the micro wave pressure digestion acc. to DIN 22022-1											
Arsenic (As)	FR	JE02	DIN EN ISO 17294-2		< 13		< 13	0,8	g/metric tonne	-	1,6
Lead (Pb)	FR	JE02	DIN EN ISO 17294-2		< 150		< 120	2	g/metric tonne	-	4
Cadmium (Cd)	FR	JE02	DIN EN ISO 17294-2		< 1,5		< 1	0,2	g/metric tonne	-	0,5
Copper (Cu)	FR	JE02	DIN EN ISO 17294-2		< 100		< 100	1	g/metric tonne	-	702
Nickel (Ni)	FR	JE02	DIN EN ISO 17294-2		< 50		< 30	1	g/metric tonne	-	31
Mercury (Hg)	FR	JE02	DIN 22022-4		< 1		< 1	0,07	g/metric tonne	-	< 0,07
Zinc (Zn)	FR	JE02	DIN EN ISO 17294-2		< 400		< 400	1	g/metric tonne	-	2580
Chromium (Cr)	FR	JE02	DIN EN ISO 17294-2		< 90		< 80	1	g/metric tonne	-	33
Boron (B)	FR	JE02	DIN EN ISO 17294-2					1	mg/kg	-	91
Manganese (Mn)	FR	JE02	DIN EN ISO 17294-2					1	mg/kg	-	1570
Elements fr. the borate digestion acc. to DIN 51729-1/-11 after inciner. (550°C)											
Phosphorus as P2O5	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	20,4
Magnesium as MgO	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	11,9
Calcium as Calciumoxid	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	24,5
Potassium as K20	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	6,8
Sodium as Na2O	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	1,8
Iron as Fe2O3	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	2,9
Silicon as SiO2	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	19,2
sulphur as SO3	FR	JE02	DIN EN ISO 11885					0,1	% (w/w)	-	3,5

				Limit values				Description		Pig Char	
								Sample number		117123065	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
DIN 51729-1/-11 after inciner. (550°C)-ref. OS											
Calcium (Ca)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	10,6
Iron (Fe)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	1,2
Potassium (K)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	3,4
Magnesium (Mg)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	4,3
Sodium (Na)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	0,8
Phosphorus	FR	JE02	DIN EN ISO 11885						% (w/w)	-	5,4
Sulphur (S)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	0,8
Silicon (Si)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	5,4
Elements from toluene extraction											
Naphthalene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	0,3
Acenaphthylene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Acenaphthene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Fluorene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Phenanthrene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	0,1
Anthracene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Fluoranthene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Pyrene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Benz(a)anthracene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Chrysene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Benzo(b)fluoranthene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Benzo(k)fluoranthene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Benzo(a)pyrene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Indeno(1,2,3-cd)pyrene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Dibenz(a,h)anthracene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Benzo(g,h,i)perylene	FR	JE02	analog DIN EN 15527					0,1	mg/kg	-	< 0,1
Total 16 EPA-PAH excl. LOQ	FR	JE02	analog DIN EN 15527		< 12		< 4		mg/kg	-	0,4

Explanations

LOQ - Limit of quantification

ar - as received

db - dry basis

Lab - Abbreviation of the performing laboratory

Accr. - Abbreviation of the accreditation of the performing laboratory

The parameters identified by FR have been performed by the laboratory Eurofins Umwelt Ost GmbH (Bobritzsch-Hilbersdorf). The accreditation code JE02 identifies the parameters accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14081-01-00 .

The parameters identified by GF have been performed by the laboratory Eurofins GfA Lab Service GmbH (Hamburg). The accreditation code A026 identifies the parameters accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14629-01-00 .

The parameters identified by SB99 have been performed by the laboratory GEOS Freiberg (Freiberg).

The parameters identified by SUIB have been performed by the laboratory TU Bergakademie Freiberg (IEC) (Freiberg).

/o - The analysis has been outsourced.

Explanations regarding Limits

Analysis performed according to guidelines for sustainable production of biochar of the european biochar certificate.
GW 1: basic quality grade (refered to dry basis)
GW 2: premium quality grade (refered to dry basis)

Ho,V / Hu,p: complies calorific value at constant volume or pressure

EUROFINS UMWELT assumes no responsibility for the legal liability of the cited limits.

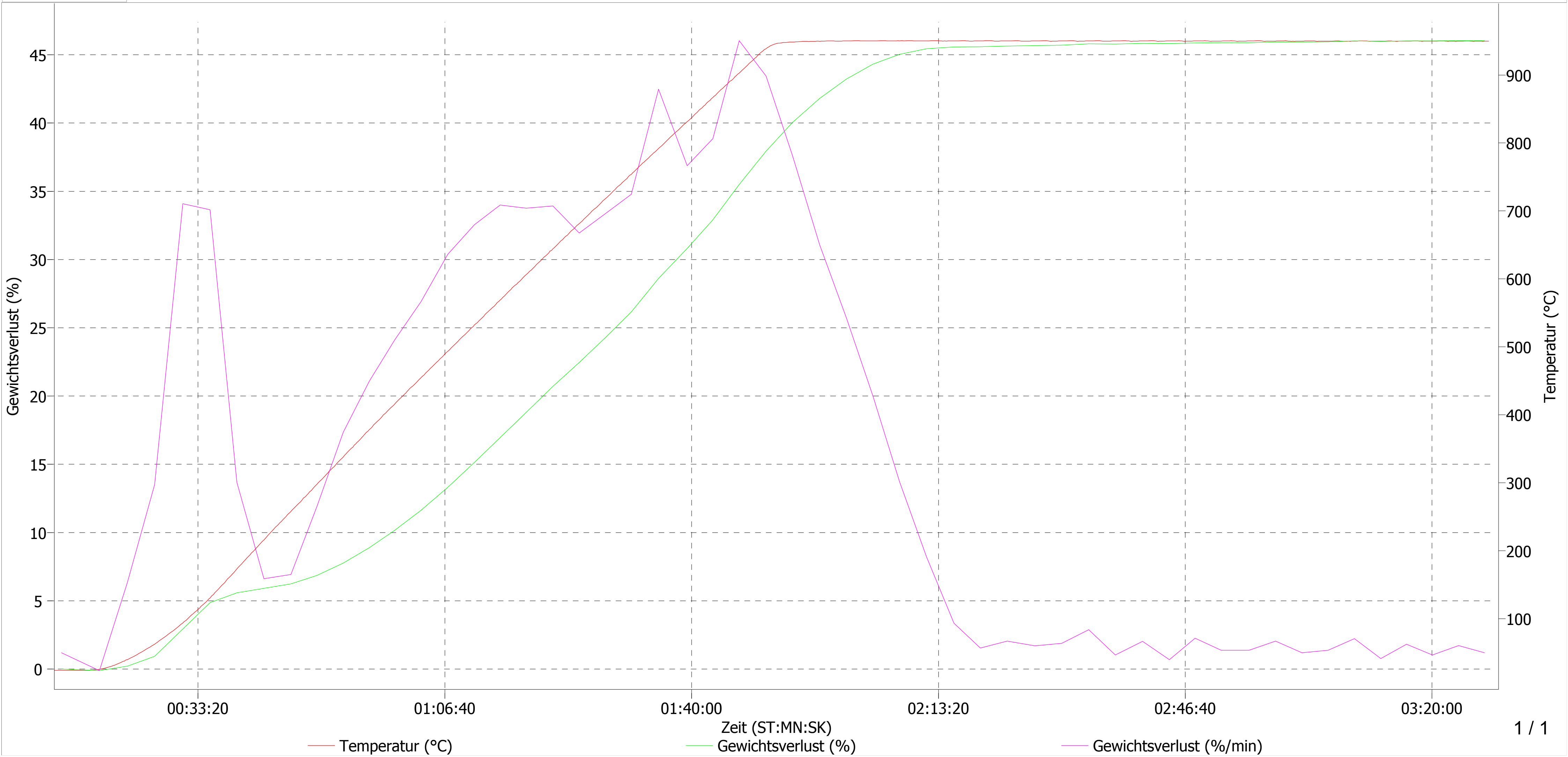
Attachment to report AR-18-FR-001350-01 : 117123065-1

TGA701

1/11/2018 11:33:50 AM

Name	Position	Kommentar	Methode	Ausgangsgewicht	Wasser	W 40	GV 360	Asche 550	Asche 775	Asche 800	Asche 810	Asche 815	Asche 975	TGA 950	Datum der Analyse	(wf) GV 550
117123065	15	gaus	TGA 950 N (Pflanze	1.0148										46.04	1/11/2018 11:22:29 AM	

TGA 950
46.04



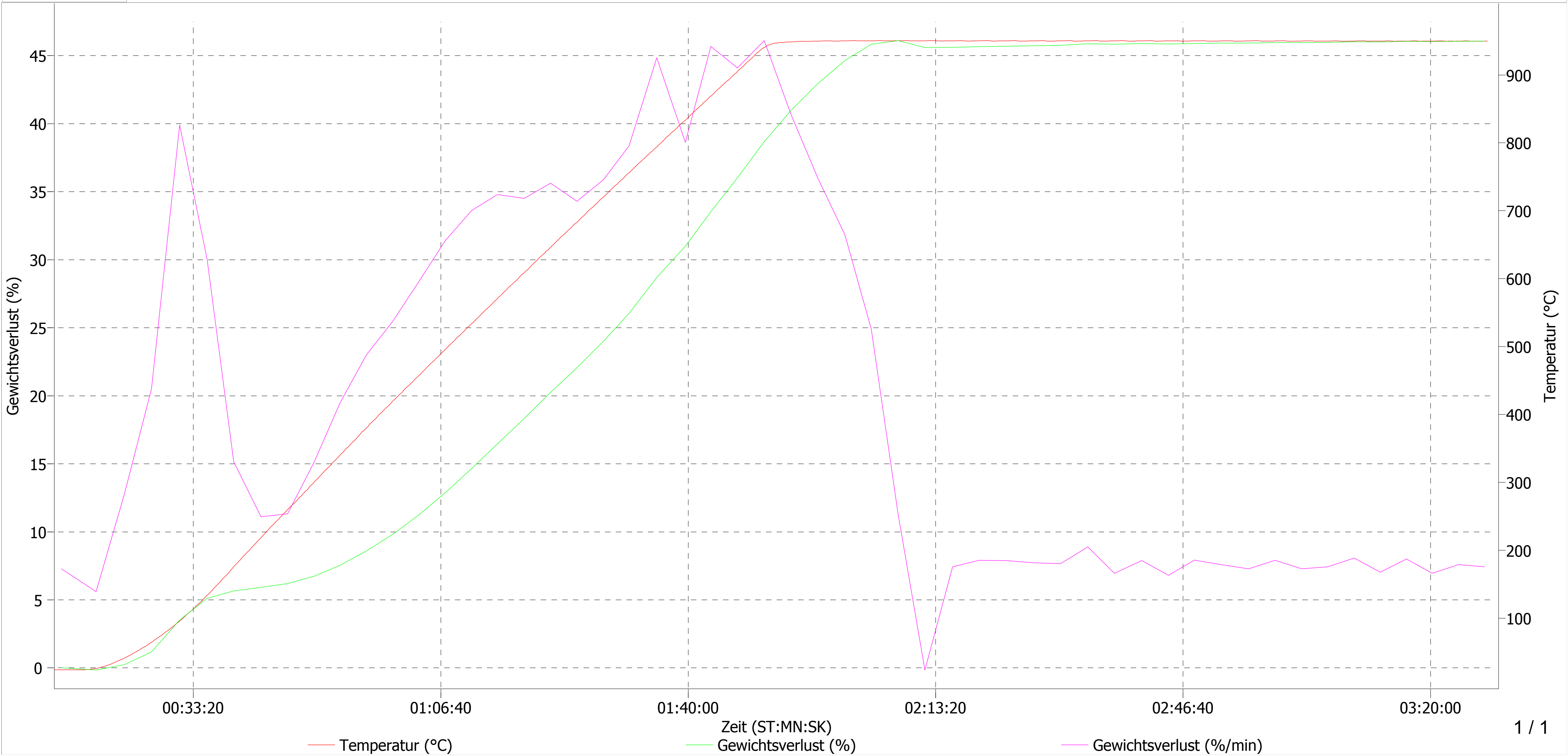
TGA701

Attachment to report AR-18-FR-001350-01 : 117123065-2

1/11/2018 11:34:45 AM

Name	Position	Kommentar	Method e	Ausgang sgewicht	Wasser	W 40	GV 360	Asche 550	Asche 775	Asche 800	Asche 810	Asche 815	Asche 975	TGA 950	Datum der Analyse	(wf) GV 550
117123065	16	gaus	TGA 950 N (Pflanze	0.9367										46.07	1/11/2018 11:22:30 AM	

TGA 950
46.07



Eurofins Umwelt Ost GmbH - Lindenstraße 11
Gewerbegebiet Freiberg Ost - D-09627 - Bobritzsch-Hilbersdorf

Wageningen University and Research
Animal Science Group, Livestock Research
Postbus 2176
8203 AD Lelystad
the NETHERLANDS

Title :	**Test report for order 11801687**
Test report number :	**AR-18-FR-002908-01**
Project name :	**analysis of biochar**
Number of samples :	**1**
Sample type :	**biochar**
Sample Taker:	**Client**
Sample reception date :	**2018-01-24**
Sample processing time :	**2018-01-25 - 2018-02-09**

The test results refer solely to the analysed test specimen. Unless the sampling was done by our laboratory or in our sub-order the responsibility for the correctness of the sampling is disclaimed. This test report is only valid with signature and may only be further published completely and unchanged. Extracts or changes require the authorisation of the EUROFINS UMWELT in each individual case.

Our General Terms & Conditions of Sale (GTCS) are applicable, as far as no specific agreements do exist. The GTCS are available on http://www.eurofins.de/umwelt/avb.aspx.

Accredited test laboratory according to DIN EN ISO/IEC 17025 notification under the DAkkS German Accreditation System for Testing. The laboratory is according (D-PL-14081-01-00) accredited.

Attachments

118005770-1
118005770-2

William Homilius	Digitally signed 09.02.2018
Analytical Services Manager	William Homilius
Phone +49 3731 2076516	Prüfleitung

DAkkS
Deutsche Akkreditierungsstelle
D-PL-14081-01-00

eurofins Umwelt

								Description		biochar	
				Limit values				Sample number		118005770	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Biochar properties											
Bulk density	FR	JE02	DIN 51705						kg/m^3	533	-
specific surface (BET)	SUIB/o		DIN 66137/DIN ISO 9277						m^2/g	105.5414	-
true density	SUIB/o		DIN 66137/DIN ISO 9277						g/cm^3	2.2813	-
water holding capacity (WHC)	SB99/o		DIN ISO 14238, A						% (w/w)	81.2	-
Moisture	FR	JE02	DIN 51718					0.1	% (w/w)	9.7	-
Ash content (550°C)	FR	JE02	DIN 51719 mod.					0.1	% (w/w)	60.7	67.1
Ash content (815°C)	FR	JE02	DIN 51719					0.1	% (w/w)	58.2	64.4
Volatile Compounds	FR	JE02	DIN 51720					0.2	% (w/w)	8.7	9.7
gross calorific value (Ho,V)	FR	JE02	DIN 51900					200	kJ/kg	8340	9230
net calorific value (Hup)	FR	JE02	DIN 51900					200	kJ/kg	8170	9310
Hydrogen	FR	JE02	DIN 51732					0.1	% (w/w)	< 0.1	< 0.1
Carbon	FR	JE02	DIN 51732		> 50		> 50	0.2	% (w/w)	25.7	28.4
Total nitrogen	FR	JE02	DIN 51732					0.05	% (w/w)	0.28	0.31
Oxygen	FR	JE02	DIN 51733, berechnet						% (w/w)	6.3	6.9
Total inorganic carbon (TIC)	FR	JE02	DIN 51726					0.1	% (w/w)	1.1	1.2
carbonate-CO2	FR	JE02	DIN 51726					0.4	% (w/w)	4.1	4.5
carbon (organic)	FR	JE02	berechnet						% (w/w)	24.6	27.2
H/C ratio (molar)	FR	JE02	berechnet		< 0.6		< 0.6			0.00	0.00
H/Corg ratio (molar)	FR	JE02	berechnet		< 0.7		< 0.7			0.00	0.00
O/C ratio (molar)	FR	JE02	berechnet		< 0.4		< 0.4			0.184	0.182
Sulphur (S), total	FR	JE02	DIN 51724-3					0.03	% (w/w)	0.26	0.28
pH in CaCl2	FR	JE02	DIN ISO 10390	10		10				10.6	-
Conductivity	FR		BGK III. C2					5	µS/cm	5410	-
salt content	FR		BGK III. C2					0.005	g/kg	28.6	31.6
salt content	FR		BGK III. C2					0.005	g/l	15.2	16.9
thermogravimetry TGA 950°C by N-Atm.	FR		TGA 701 D4C							siehe Anlage	-

				Limit values				Description		biochar	
								Sample number		118005770	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Polychlorinated dibenzodioxins/-furans (17 PCDD/F) by GC-HRMS											
2,3,7,8-TetraCDD	GF/o	A026	Internal method					0.18	ng/kg dw	-	< 0.17
1,2,3,7,8-PentaCDD	GF/o	A026	Internal method					0.24	ng/kg dw	-	< 0.23
1,2,3,4,7,8-HexaCDD	GF/o	A026	Internal method					0.48	ng/kg dw	-	< 0.46
1,2,3,6,7,8-HexaCDD	GF/o	A026	Internal method					0.48	ng/kg dw	-	< 0.46
1,2,3,7,8,9-HexaCDD	GF/o	A026	Internal method					0.48	ng/kg dw	-	< 0.46
1,2,3,4,6,7,8-HeptaCDD	GF/o	A026	Internal method					0.54	ng/kg dw	-	1.2
OctaCDD	GF/o	A026	Internal method					2.2	ng/kg dw	-	6.3
2,3,7,8-TetraCDF	GF/o	A026	Internal method					0.32	ng/kg dw	-	< 0.31
1,2,3,7,8-PentaCDF	GF/o	A026	Internal method					0.44	ng/kg dw	-	< 0.42
2,3,4,7,8-PentaCDF	GF/o	A026	Internal method					0.44	ng/kg dw	-	< 0.42
1,2,3,4,7,8-HexaCDF	GF/o	A026	Internal method					0.40	ng/kg dw	-	< 0.38
1,2,3,6,7,8-HexaCDF	GF/o	A026	Internal method					0.40	ng/kg dw	-	< 0.38
1,2,3,7,8,9-HexaCDF	GF/o	A026	Internal method					0.40	ng/kg dw	-	< 0.38
2,3,4,6,7,8-HexaCDF	GF/o	A026	Internal method					0.40	ng/kg dw	-	< 0.38
1,2,3,4,6,7,8-HeptaCDF	GF/o	A026	Internal method					0.52	ng/kg dw	-	< 0.48
1,2,3,4,7,8,9-HeptaCDF	GF/o	A026	Internal method					0.38	ng/kg dw	-	< 0.35
OctaCDF	GF/o	A026	Internal method					3.2	ng/kg dw	-	< 2.9
WHO(2005)-PCDD/F TEQ (lower-bound)	GF/o	A026	Internal method		< 20		< 20		ng/kg dw	-	0.0134
WHO(2005)-PCDD/F TEQ (upper-bound)	GF/o	A026	Internal method					0.92	ng/kg dw	-	< 0.92

Parameter	Lab	Accr.	Method	Limit values GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	LOQ	Unit	biochar 118005770 ar	db
Polychlorinated biphenyl (12 WHO PCB) by GC-HRMS											
PCB 77	GF/o	A026	Internal method					3.6	ng/kg dw	-	< 3.5
PCB 81	GF/o	A026	Internal method					0.78	ng/kg dw	-	< 0.75
PCB 105	GF/o	A026	Internal method					7.8	ng/kg dw	-	< 7.5
PCB 118	GF/o	A026	Internal method					28	ng/kg dw	-	54
PCB 114	GF/o	A026	Internal method					0.94	ng/kg dw	-	< 0.90
PCB 123	GF/o	A026	Internal method					0.80	ng/kg dw	-	< 0.77
PCB 126	GF/o	A026	Internal method					1.0	ng/kg dw	-	< 0.98
PCB 156	GF/o	A026	Internal method					4.4	ng/kg dw	-	12
PCB 157	GF/o	A026	Internal method					0.90	ng/kg dw	-	1.1
PCB 167	GF/o	A026	Internal method					2.2	ng/kg dw	-	7.2
PCB 169	GF/o	A026	Internal method					2.4	ng/kg dw	-	< 2.3
PCB 189	GF/o	A026	Internal method					0.80	ng/kg dw	-	< 0.77
WHO(2005)-PCB TEQ (lower-bound)	GF/o	A026	Internal method						ng/kg dw	-	0.00223
WHO(2005)-PCB TEQ (upper-bound)	GF/o	A026	Internal method					0.17	ng/kg dw	-	0.17
WHO(2005)-PCDD/F+PCB TEQ (lower-bound)	GF/o	A026	Internal method						ng/kg	0.0156	-
WHO(2005)-PCDD/F+PCB TEQ (upper-bound)	GF/o	A026	Internal method						ng/kg	1.06	-

								Description		biochar	
				Limit values				Sample number		118005770	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Polychlorinated biphenyl (7 PCB) by GC-HRMS											
PCB 28	GF/o	A026	Internal method					0.082	µg/kg dw	-	< 0.079
PCB 52	GF/o	A026	Internal method					0.061	µg/kg dw	-	< 0.059
PCB 101	GF/o	A026	Internal method					0.098	µg/kg dw	-	0.15
PCB 118	GF/o	A026	Internal method					0.028	µg/kg dw	-	0.054
PCB 138	GF/o	A026	Internal method					0.072	µg/kg dw	-	0.16
PCB 153	GF/o	A026	Internal method					0.12	µg/kg dw	-	0.24
PCB 180	GF/o	A026	Internal method					0.030	µg/kg dw	-	0.075
Total 6 ndl-PCB (lower-bound)	GF/o	A026	Internal method		< 200		< 200		µg/kg dw	-	0.629
Total 6 ndl-PCB (upper-bound)	GF/o	A026	Internal method						µg/kg dw	-	0.766
Total 7 Indicator PCB (lower-bound)	GF/o	A026	Internal method		< 200		< 200		µg/kg dw	-	0.683
Total 7 Indicator PCB (upper-bound)	GF/o	A026	Internal method					0.46	µg/kg dw	-	0.82

				Limit values				Description		biochar	
								Sample number		118005770	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
Elements from the micro wave pressure digestion acc. to DIN 22022-1											
Arsenic (As)	FR	JE02	DIN EN ISO 17294-2		< 13		< 13	0.8	g/metric tonne	-	2.6
Lead (Pb)	FR	JE02	DIN EN ISO 17294-2		< 150		< 120	2	g/metric tonne	-	2
Cadmium (Cd)	FR	JE02	DIN EN ISO 17294-2		< 1.5		< 1	0.2	g/metric tonne	-	< 0.2
Copper (Cu)	FR	JE02	DIN EN ISO 17294-2		< 100		< 100	1	g/metric tonne	-	96
Nickel (Ni)	FR	JE02	DIN EN ISO 17294-2		< 50		< 30	1	g/metric tonne	-	117
Mercury (Hg)	FR	JE02	DIN 22022-4		< 1		< 1	0.07	g/metric tonne	-	< 0.07
Zinc (Zn)	FR	JE02	DIN EN ISO 17294-2		< 400		< 400	1	g/metric tonne	-	139
Chromium (Cr)	FR	JE02	DIN EN ISO 17294-2		< 90		< 80	1	g/metric tonne	-	176
Boron (B)	FR	JE02	DIN EN ISO 17294-2					1	mg/kg	-	62
Manganese (Mn)	FR	JE02	DIN EN ISO 17294-2					1	mg/kg	-	829
Elements fr. the borate digestion acc. to DIN 51729-1/-11 after inciner. (550°C)											
Phosphorus as P2O5	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	12.5
Magnesium as MgO	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	9.6
Calcium as Calciumoxid	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	17.9
Potassium as K20	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	11.3
Sodium as Na2O	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	2.4
Iron as Fe2O3	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	2.3
Silicon as SiO2	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	32.6
sulphur as SO3	FR	JE02	DIN EN ISO 11885					0.1	% (w/w)	-	1.1

								Description		**biochar**	
				Limit values				**Sample number**		**118005770**	
Parameter	**Lab**	**Accr.**	**Method**	GW 1 ar	GW 1 db	GW 2 ar	GW 2 db	**LOQ**	**Unit**	**ar**	**db**
DIN 51729-1/-11 after inciner. (550°C)-ref. OS											
Calcium (Ca)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	8.6
Iron (Fe)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	1.1
Potassium (K)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	6.3
Magnesium (Mg)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	3.9
Sodium (Na)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	1.2
Phosphorus	FR	JE02	DIN EN ISO 11885						% (w/w)	-	3.7
Sulphur (S)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	0.3
Silicon (Si)	FR	JE02	DIN EN ISO 11885						% (w/w)	-	10.2
Elements from toluene extraction											
Naphthalene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Acenaphthylene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Acenaphthene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Fluorene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Phenanthrene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Anthracene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Fluoranthene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Pyrene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Benz(a)anthracene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Chrysene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Benzo(b)fluoranthene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Benzo(k)fluoranthene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Benzo(a)pyrene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Indeno(1,2,3-cd)pyrene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Dibenz(a,h)anthracene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Benzo(g,h,i)perylene	FR	JE02	analog DIN EN 15527					0.1	mg/kg	-	< 0.1
Total 16 EPA-PAH excl. LOQ	FR	JE02	analog DIN EN 15527		< 12		< 4		mg/kg	-	(n. c.) [1]

Explanations

LOQ - Limit of quantification

ar - as received

db - dry basis

Lab - Abbreviation of the performing laboratory

Accr. - Abbreviation of the accreditation of the performing laboratory

Comments for results

[1)] not calculable, as all results < loq.

The parameters identified by FR have been performed by the laboratory Eurofins Umwelt Ost GmbH (Bobritzsch-Hilbersdorf). The accreditation code JE02 identifies the parameters accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14081-01-00 .

The parameters identified by GF have been performed by the laboratory Eurofins GfA Lab Service GmbH (Hamburg). The accreditation code A026 identifies the parameters accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14629-01-00 .

The parameters identified by SB99 have been performed by the laboratory GEOS Freiberg (Freiberg).

The parameters identified by SUIB have been performed by the laboratory TU Bergakademie Freiberg (IEC) (Freiberg).

/o - The analysis has been outsourced.

Explanations regarding Limits

Analysis performed according to guidelines for sustainable production of biochar of the european biochar certificate.
GW 1: basic quality grade (refered to dry basis)
GW 2: premium quality grade (refered to dry basis)

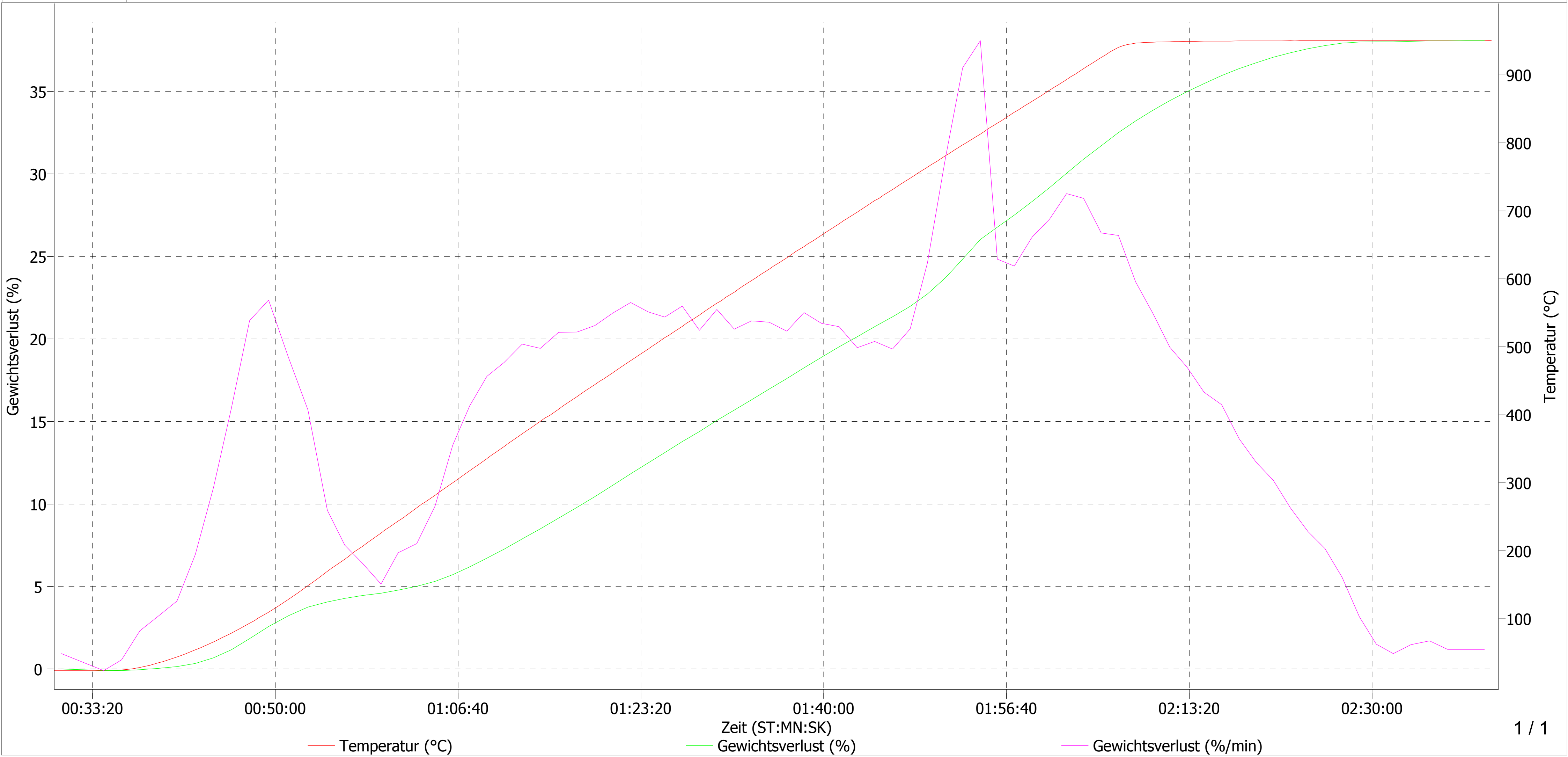
Ho,V / Hu,p: complies calorific value at constant volume or pressure

EUROFINS UMWELT assumes no responsibility for the legal liability of the cited limits.

2/2/2018 9:07:46 AM

Name	Position	Kommentar	Methode	Ausgangsgewicht	Wasser	W 40	GV 360	Asche 550	Asche 775	Asche 800	Asche 810	Asche 815	Asche 975	TGA 950	Datum der Analyse	(wf) GV 550
118005770	5	bl5k	TGA 950 N (Pflanzen	1.1366										38.08	2/1/2018 2:55:12 PM	

TGA 950
38.08

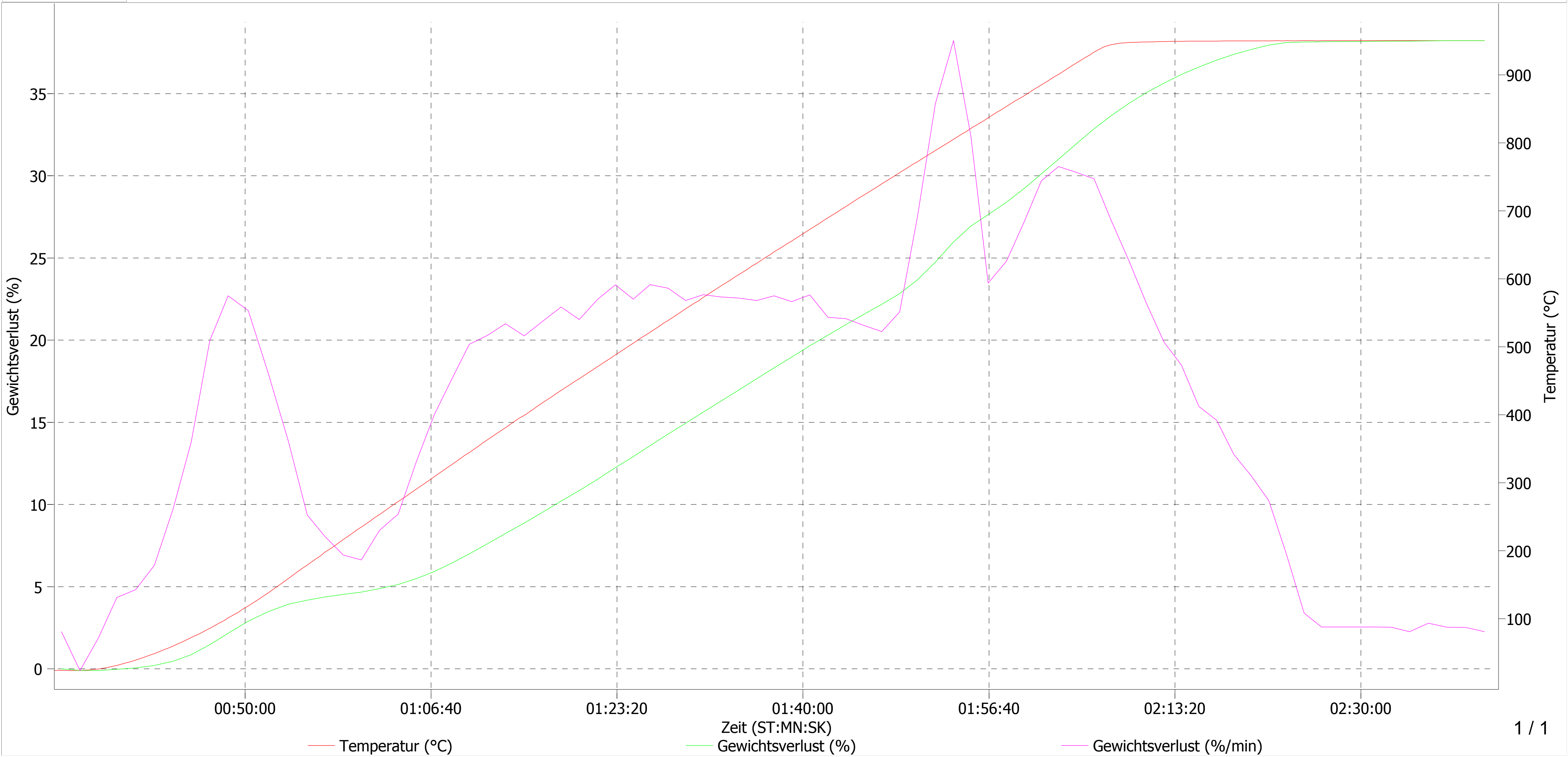


TGA701

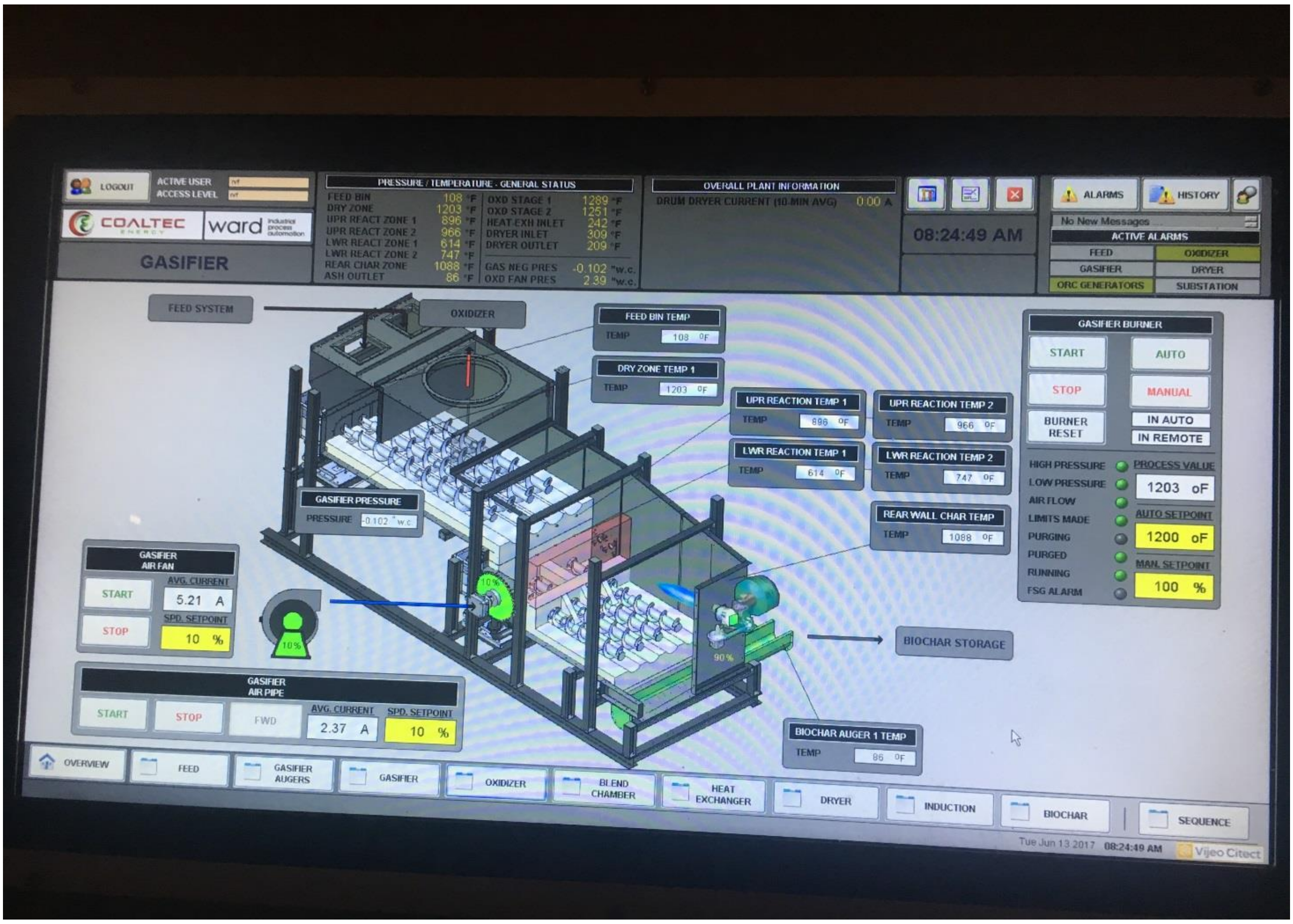
2/2/2018 9:08:31 AM

Name	Position	Kommentar	Methode	Ausgangsgewicht	Wasser	W 40	GV 360	Asche 550	Asche 775	Asche 800	Asche 810	Asche 815	Asche 975	TGA 950	Datum der Analyse	(wf) GV 550
118005770	15	bl5k	TGA 950 N (Pflanzen	1.0943										38.23	2/1/2018 2:55:12 PM	

TGA 950
38.23



Appendix 2 Picture of the gasifier control screen (source MAVITEC)



Appendix 3 National, voluntary and proposed criteria for biochar, biological tests

Quality requirements	National legislation				Voluntary					Proposal EU regulation, JRC-STRUBIAS
	DE	**AT**	**CH**	**IT**	**IBI-BS**	**EBC Basic grade**	**EBC Pre-mium**	**BQM Standard grade**	**BQM High Grade**	
Germination test	-	-	-	Reporting obligation	pass	-	-	-	-	-
Worm avoidance test	-	-	-		-	-	-	-	-	proposed
Labeling										Particle density, specific surface area and volatile matter

Appendix 4 National, voluntary and proposed criteria for biochar, feedstock limitations and sustainability requirements

Quality requirements Inorganic metals and metalloids	**Unit**	**National legislation**				**Voluntary**					**Proposal EU regulation, JRC-STRUBIAS**	
		DE	**AT**	**CH**	**IT**	**IBI/BS**	**EBC Basic grade**	**EBC Pre-mium**	**BQM Stan-dard grade**	**BQM High Grade**		
		Fertilizer Ordinance	**Fertilizer Ordinance Soil Improvers etc.**	**Fertilizer Ordinance**	**Fertilizer Decree**						**C-rich**	**Nutrient-rich**
Feedstock limitations		Yes (1)	-	Yes (1)	Yes (2)	Yes (3)	Yes (4)		Yes (5)		Positive input material list (6)	
Feedstock sustainability requirements		Detailed require-ments	-	-	-		Yes		Detailed requirements		Possible, currently under investigation	

1: Only chemically untreated wood; 2: Biomass of vegetable origin from agriculture and forestry, olive pomace, grape marcs, cereals bran, fruit stones and wood shells, non-treated residues of wood processing; 3: No hazardous municipal solid waste ; 4: Detailed list of permitted feedstock’s ; 5: Only biomass feedstock’s; 6: vegetable waste, wood waste and bio-waste and animal by-products of category II and III.

Appendix 5 National, voluntary and proposed criteria for biochar, production method

Aditional requirements	National legislation				Voluntary					Proposal EU Regulation (STRUBIAS)
	DE	AT	CH	IT	IBI/BS	EBC basic grade	EBC premium	BQM standard grade	BQM	
Admitted production technologies	Not specified	Not specified	Pyrolysis and gasification	Pyrolysis and gasification	Not specified	Pyrolysis and gasification	Pyrolysis and gasification	Not specified	Not specified	Stand-alone installation, no requirements for pre-processing
Minimum/ Maximum process temperature	-	-	-	-	-	Min: 350°C max 1000°C	Min: 350°C max 1000°C	-	-	pyrolysis profile of > 500˚C for > 20 minutes; >175˚C, >2 seconds for designated uncontaminated input materials (A)
Admitted PAH analysis methods	n.a.	Methods according to the stat-of-the-art of science and technology	Extraction solvent toluene mandatory	Not defined	Soxhlet with toluene (EPA 8270 EPA 3540	DIN EN 15527:2008-09 WITH TOLUENE/ DIN ISO 13887:1995-06: Principle B	DIN EN 15527:2008-09 WITH TOLUENE/ DIN ISO 13887:1995-06: Principle B	DIN EN 15527:2008-09 WITH TOLUENE/ DIN ISO 13887:1995-06: Principle B	DIN EN 15527:2008-09 WITH TOLUENE/ DIN ISO 13887:1995-06: Principle B	Not defined yet
GHG balance standard for biochar product	-	-	Standards to avoid GHG emissions	-	-	Standards to avoid GHG	Standards to avoid GHG	Positive GHG balance obligatory	Positive GHG balance obligatory	-
On-site verification	-	-	Yes	-	-	-	-	-	-	-

Appendix 6 Product function categories

1. Fertiliser
    - A. Organic fertiliser
        - I. Solid organic fertiliser
        - II. Liquid organic fertiliser
    - B. Organo-mineral fertiliser
        - I. Solid organo-mineral fertiliser
        - II. Liquid organo-mineral fertiliser
    - C. Inorganic fertiliser
        - I. Inorganic macronutrient fertiliser
            - a) Solid inorganic macronutrient fertiliser
                - i) Straight solid inorganic macronutrient fertiliser
                    - A) Straight solid inorganic macronutrient ammonium nitrate fertiliser of high nitrogen content
                - ii) Compound solid inorganic macronutrient fertiliser
                    - A) Compound solid inorganic macronutrient ammonium nitrate fertiliser of high nitrogen content
            - b) Liquid inorganic macronutrient fertiliser
                - i) Straight liquid inorganic macronutrient fertiliser
                - ii) Compound liquid inorganic macronutrient fertiliser
        - II. Inorganic micronutrient fertiliser
            - a) Straight inorganic micronutrient fertiliser
            - b) Compound inorganic micronutrient fertiliser
2. Liming material

3. Soil improver
    - A. Organic soil improver
    - B. Inorganic soil improver

4. Growing medium

5. Inhibitor
    - A Nitrification inhibitor
    - B Urease inhibitor
    - C. Denitrification inhibitor

6. Plant biostimulant
    - A. Microbial plant biostimulant
    - B. Non-microbial plant biostimulant

7. Fertilising product blend

Appendix 7 Component material categories

CMC 1: Virgin material substances and mixtures

CMC 2: Non-processed or mechanically processed plants, plant parts or plant extracts

CMC 3: Compost

CMC 4: Energy crop digestate

CMC 5: Other digestate than energy crop digestate

CMC 6: Food industry by-products

CMC 7: Micro-organisms

CMC 8: Agronomic additives

CMC 9: Nutrient polymers

CMC 10: Other polymers than nutrient polymers

CMC 11: Certain animal by-products

To explore the potential of nature to improve the quality of life

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Wageningen Livestock Research creates science based solutions for a sustainable and profitable livestock sector. Together with our clients, we integrate scientific knowledge and practical experience to develop livestock concepts for future generations.

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