

Review WUR - WEnR

STRUBIAS Technical Proposals

Dries Huygens, Hans Saveyn, Peter Eder & Luis Delgado Sancho, 2017. *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*

This review of Wageningen University & Research – Wageningen Environmental Research (WUR –WenR (Alterra)) gives general and detailed remarks.

General remarks

The interim report reads well and the index is logical and transparent. Some general remarks are made.

- I. The categorisation of wastes in different component material categories (CMC) is not always coherent (see detailed remarks). STRUBIAS materials from manure, digestates of manure and bio-waste and waste water treatment plants are in general not yet covered by currently proposed CMC. STRUBIAS materials from animal by-products have to be included in the table of CMC 11 given the current structure of the new fertiliser regulation. Perhaps for STRUBIAS materials an exemption can be made for materials that will be placed in a new CMC designated to STRUBIAS materials. This will lead however to a delay in CE marking of STRUBIAS materials that currently are traded within EU.
- II. The term nutrient recovery rules is the current phrase for recovering valuable components from renewable sources used by the European Commission. As such the term is rightly used. In a technical report however it serves to specify what is meant with nutrient recovery rules as the term literally does not cover all value giving components of STRUBIAS materials. Acid neutralising value (liming materials) and organic carbon are in strict sense excluded. Why not rules for renewable fertilising products?
- III. Micronutrients B, Co, Mn and Mo are assessed as contaminants. Indeed too high concentrations of these elements are (phyto)toxic. However these elements also serve as a micronutrient. The function of micronutrient is not included in the evaluation. This is considered as an omission more over as for other CMC's no criteria for environmental safety are formulated while these other CMC's are also sources of these elements (example given: boron in liming materials).

The proposed methodology for risks assessment lead to the following general remarks.

- IV. Approach to assess risks and/or acceptable levels for the 3 STRUBIAS materials are markedly different. For struvite a best practice approach is proposed based on current levels in products that can be reasonably expected to be produced whereas a risk based approach is followed for biochar and ashes.
- V. No clear reasoning is given as to why standards for currently non regulated metals and metalloids are needed (i.e. for metals like V, Sb, etc.). In the NL such compounds are not regulated for soil either because there are no issues recorded in relation to these metals or data to derive meaningful standards are not available.
- VI. The risk assessment approach as used for ashes and biochar seems to be insufficiently robust given the assumptions made, in particular referring to the Kd approach used which is known to be highly variable rather than constant for all soils as is implicitly assumed here. The final risk based values as derived here therefor can be equally variable depending on the value used for Kd (see detailed comments).
- VII. For non-regulated metals and metalloids an alternative approach can be proposed which involves an assessment (country or regional) of long term (100 years) impact of using either of these products based on current known composition data (P95 or likewise to represent realistic worst case) on levels in soils and related environmental compartments (crops/water if relevant, see detailed comments).

Detailed remarks

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
...specific secondary raw materials, including waste and by-products...	1, page 1, line 20	Secondary raw materials, including waste and by-products is a confusing statement as secondary raw materials (or recycled wastes) have reached an end-of-waste status		
Recovery of nutrients and organic matter	1, page 1, line 23	The term nutrient recovery rules is the current phrase for recovering valuable components from renewable sources used by the European Commission. As such the term is rightly used. In a technical report however it serves to specify what is meant with nutrient recovery rules as the term literally does not cover all value giving components of STRUBIAS materials. Acid neutralising value (liming materials) and organic carbon are in strict sense excluded. Why not rules for renewable fertilising products?		
However, treatments...	1, page 2, line 48-49	Why is a recovery operation not a normal industrial practice? This statement is in conflict with a focus on a circular economy. Currently, several types of fertilising products that meet requirement of the EU regulation on fertilisers 2003/2003 and are traded with the marking 'EC fertiliser' are reusing nutrients or acid neutralising value (e.g. NPK fertilisers produced from ashes of bone meal, dicalcium phosphate from bone meal and sugar factory lime). These recovery operations are normal industrial practices.		
Improve their nutrition efficiency	1, page 2, line 52	STRUBIAS materials are sources of nutrients, acid neutralising value and organic matter (organic carbon).		

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		<p>Focus only on nutrients and nutrition efficiency does not merit the positive effects of organic carbon on chemical, physical and biological soil fertility:</p> <ul style="list-style-type: none"> - Improvement of soil structure (aeration, stability) - Increase of capacity to store moisture storage - Effect on soil temperature through it's dark colour - Improvement of biological activity - Buffer for nutrients and pH - etc. <p>Focus only on nutrients and nutrition efficiency does not merit the positive effects of liming materials on chemical, physical and biological soil fertility:</p> <ul style="list-style-type: none"> - Establishing optimal pH for crop growth (crop differ in pH requirements) - Improvement of soil structure (aeration, stability) - Improvement of biological activity - etc. 		
III	1, page 2, line 58	This is a too restrictive condition for a current situation. To promote reuse of nutrients, acid neutralising value and organic carbon also STRUBIAS materials that show a <u>perspective for reuse</u> as a fertilising product need to be assessed.		
Main benefit	3, page 3, lines 84 - 94	The main benefit is reuse of renewable sources for nutrients, acid neutralising value and organic matter.		
Nutrient recovery rules	2, page 4, lines, 103, 104 and 119	See given comment on nutrient recovery rules.		
nutrient and organic matter	2.2, page 6, line 207	nutrients, <u>acid neutralising value</u> and organic matter		
(5) end-material safety...	2.2., page 6, line 211	(5) = (4) What is meant with <u>end-material safety</u> and quality? Environmental		

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		and human health safety aspects of <u>STRUBIAS materials as secondary raw materials?</u>		
High nutrient content	2.3, page 9, line 288	Not only nutrients, also acid neutralising value and/or organic carbon		
Plant availability of P in STRUBIAS materials	2.3, page 9, line 299	<p>The interim report is not clear in which phase a waste becomes a CMC. Is this <u>after</u> physical, thermal and/or chemical processing? This allows for postprocessing (physical processes as grinding, pellitising) and blending practices only after reaching the CMC status (and thus sets strict criteria to a CMC).</p> <p>There is no need for regulation on component material category (CMC) level the plant availability of nutrients if all forms of processing are allowed for a CMC category. Plant availability is of utmost importance for a product function category (PFC). On PFC level plant availability has to be regulated. Processing secondary raw materials may increase the plant availability of the nutrients.</p> <p>A none processed CMC material which is directly used as a PFC has to fulfil the criteria of that PFC. The same counts after processing. However CMC materials do not have to meet criteria for plant availability if they are processed first (thermal and/or chemical and/or physical).</p> <p>If a waste has to be processed first to become a CMC material, then a clear clarification of designated processes is needed. How enforcement can be carried out in this situation is not clear. Processing leads to an intermediate secondary raw material that at the same production site is further processed to a fertilising product. The intermediate is short lived.</p>		

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		Focus only on trade in STRUBIAS base materials as secondary raw material of a CMC category excludes some current practises of current production of fertilising products (also some which are traded as EC fertiliser (EC regulation 2003/2003)).		
effictive	2.3, page 9, line 312	Effictive = effective		
P-fertilisers	2.3, page 9, line 329	STRUBIAS materials can amongst others be sources of phosphorus but also for other nutrients (K, Mg, Ca), acid neutralising value and organic carbon		
Questions	2.3, page 10, lines 352-359	<p>a. The answer of the most suitable universal manner to assess plant P availability: bioassay test or chemical extraction methods depends of the purpose for assessment. In general there is not a single method available that can serve as a universal method as chemical and physical composition of the P source, plant species with their specific P demands and physiology, soil characteristics, management practices and climate all exert an effect on the availability of phosphorus to the crop.</p> <p>This study however is conducted within the framework of a new European Fertiliser Regulation. Within this framework conformity assessment based on chemical extractants is the standard. There is from a conformity assessment within this European framework no need to change that to a bioassay although bioassays may give a more reliable estimate of the fertiliser replacement value of nutrients from secondary raw materials for a given climate * crop * soil * P-source combination.</p>		For literature see annex 1

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		<p>Current chemical methods for determining phosphorus availability in fertilisers are all based on long term experiences with mineral phosphorus fertilisers. Each method (NAC¹, NAC+W, AAC, FA, CA, MA) method has a proven agronomic effectivity (see amongst others Schnug & De Kok, 2016, Kratz et al, 2016). Long term experiences with P availability of phosphorus of recycled fertilising products (manure not included) are gradually building up. The P availability of recycled fertilising products varies. This variation is attributed to differences in composition of the fertilising product, test crop, soil, management practises and experimental conditions. Not surprisingly, published experiences differ (see annex 1). And alternatives are proposed. Instead of chemical extractants sink based extractants are proposed (Duboc et al, 2017). Or extractants uses for soil testing are proposed (Severin et al, 2014).</p> <p>b. A criterion for 2% citric acid soluble P/total P > 0.4 for a CMC material is not needed if all forms of processing are allowed. If blending is only allowed, than a criterion is needed.</p> <p>PFC criteria determine the fertiliser quality on P availability.</p> <p>A criterion of 0.4 is – in general - however feasible for recovered phosphate salts and ashes.</p> <p>c. Annex 1 provides literature with data on alternative extractants.</p>		

¹ NAC, neutral ammonium citrate, NAC+W neutral ammonium citrate and water, AAC alkaline ammonium citrate, FA formic acid, CA citric acid, MA mineral acid.

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An intermediate raw material	2.4, page 11, lines 377	What is meant with 'an intermediate raw material'? A secondary raw material ?		
End-materials....	2.4, page 11, lines 378-380	<p>The end material is a PFC. The PFC should have an agronomic effectivity as fertilising product. A component material category however can serve as a secondary raw material which before processing should have only a scope for reuse as a nutrient source for fertiliser production. After processing to a fertiliser product the regulatory requirement of an PFC counts. Scope is not the same as a demonstrated agricultural efficiency.</p> <p>CMC should have a demonstrated agricultural efficiency only if the material is directly used as a fertilising product but then the PFC criterions count. A strict criterion for a demonstrated agricultural efficiency should therefore not be a requirement unless only blending of a CMC material will be allowed.</p> <p>The use of the STRUBIAS material determines if a high concentrated material is needed. FOR organic and organo-mineral fertiliser production from secondary raw materials, lower nutrient contents are acceptable.</p>		
REACH registration as fertilisers	2.4, page 11, lines 391-392	<p>The potassium P-salts are not mentioned although their production is current practice.</p> <p>Is a registration of a CMC material as fertiliser needed? CMC materials can amongst others serve as secondary raw material for fertiliser production.</p> <p>REACH registration mentions 252 different P salts of which some can also serve as (secondary) raw material for a fertilising product. Annex 2 gives an indicative list of</p>	REACH is based on the production of mineral fertilisers with high nutrient content.	<p>Annex 2</p> <p>Source:</p> <p>https://echa.europa.eu/information-on-chemicals/registered-substances</p>

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		these P-salts that are registered pursuant to Regulation EX No 1906/2006 (REACH) and which can possibly serve as material for production of a P fertilising product		
pH range	2.4, page 12, line 400	<p>Within a pH range of 9.0 – 10.7 K-struvite can be formed. The matrix in which the reaction occurs, determines which products are formed.</p> <p>This paragraph makes clear why pure struvite (ammonium magnesium orthophosphate) is only one of the – many – P-salts that are precipitated. This paragraph has our full support!</p> <p>Post treatment of P precipitates can also alter the chemical species.</p>	<p>The pH is an important factor determining which products will be formed (Lindsay et al. 1989; Greaves et al. 1999; Le Corre et al. 2009). The following reactions may occur:</p> <ol style="list-style-type: none"> 1. Magnesium ammonium phosphate (MAP): NH₄-struvite (8.5 < pH < 9.5): $Mg^{2+} + NH_4^+ + HPO_4^{2-} + 6H_2O \rightarrow MgNH_4PO_4 \cdot 6H_2O + H^+$ 2. Magnesium potassium phosphate: K-struvite (9 < pH < 10.5): $Mg^{2+} + K^+ + HPO_4^{2-} + 6H_2O \rightarrow MgKPO_4 \cdot 6H_2O + H^+$ 3. Magnesium hydrogen phosphate (pH < 8.5): $Mg^{2+} + HPO_4^{2-} + 6H_2O \rightarrow MgHPO_4 \cdot 6H_2O$ 	<p>Greaves, J., P. Hobbs, D. Chadwick, and P. Haygarth. 1999. Prospects for the recovery of phosphorus from animal manures: A review. <i>Environmental Technology</i> 20 (7): 697-708.</p> <p>Le Corre, K. S., E. Valsami-Jones, P. Hobbs, and S. A. Parsons. 2009. Phosphorus recovery from wastewater by struvite crystallization: A review. <i>Critical Reviews in Environmental Science and Technology</i> 39 (6): 433-477. http://dx.doi.org/10.1080/10643380701640573.</p> <p>Lindsay, W. L., P. L. G. Vlek, and S. H. Chen. 1989. "Phosphate minerals." In <i>Minerals in Soil Environments. Second Edition. Soil Science Society of America Book Series; no 1. ISBN 0-89118-787-1</i>, edited by J.B. Dixon and S.B. Weed, 1089-1130.: Lindsay, W,L,., P.L.G. Vlek en S.H. Chen, , 1989. Chapter 22. Phosphate minerals. In: J.B. Dixon and S.B. Weed (Eds.), <i>Minerals in Soil Environments. Second Edition. Soil Science Society of America Book Series; no 1. ISBN 0-89118-787-1</i>, pp. 1089-1130.</p>
interest	2.4, page 12, line 418	There is also an interest for including the K-struvite	K-struvite production is a process used by Stichting Mestverwerking Gelderland.	Ehlert, P.A.I., T.A. van Dijk en O. Oenema, 2016. <i>Inclusion of struvite as a category in the Fertiliser Act; Advice</i> . Wageningen, Statutory Research Tasks Nature & Environment (WOT Natuur & Milieu), WUR, Wageningen. WOTtechnical report 69., http://edepot.wur.nl/394872
Fertiliser industry	2.4, page 13, lines 439-445	This may be valid for the fertiliser industry producing highly concentrated inorganic fertilisers currently traded with the label EC fertiliser. However secondary raw materials are currently used with much		

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		lower percentage of nutrient for the production of organic and organo-mineral fertilisers.		
Fe and Al phosphates	2.4, page 13 lines 448-449	Indeed iron phosphates or aluminium phosphates are not REACH registered as fertiliser. They do have a REACH registration as chemical.		Annex 3 https://echa.europa.eu/information-on-chemicals/registered-substances
scope	2.4, pages 13-14, lines 466-472	As Fe-P and Al-P as P-salts have no clear agronomic value as phosphate fertiliser unless the pH of the soil is alkaline. Fe-P and Al-P materials can also be used for the production of fertilising products. New developed production process removes Fe and/or Al from these materials leading to the production of Ca-P and/or Mg-P materials. This new scope in processing Fe-P and Al-P should not be ignored.		http://www.prnewswire.com/news-releases/icl---next-step-towards-sustainable-innovation-571973381.html
Question	2.4, page 14, lines 506-508	The rate of crystallisation of the recovered P salts (others than pure struvite) is not well known. It is therefore difficult to verify the proposal for the criteria. Answering the question of JRC requires new analysis of samples. This not within the scope of this review. Scientific publications on well-defined (pure) struvite crystals are available (Chen et al, 2015; Ramlogan and Rouff, 2016). The criterion for P ₂ O ₅ excludes valuable P salts. The criterion is too high. A lower value is needed. Compliance with proposals for P ₂ O ₅ content of PFC I {A (I,II), B (I,II), C (I,II) and D (I,II)} is logical: 1 – 12% P ₂ O ₅ based on the product and not on dry matter (105° C) The criterion for (Ca+Mg)/P > (molar ratio of matter) is in general not restrictive.	Annex I of the JRC interim report gives data that do not meet the criterion for phosphate (STOWA, 2015, 1 st entry, and Sigumjak et al, 2016, data of Ehlert et al 2016 (uploaded in November 2016)). The assumption that all P-salt are struvite and thus contain 44% water in the struvite crystals cannot be verified and is not in line with the description of recovered phosphate salts pages 11 and 12. Presumably the Organic C of Sigumjak et al (2016) is 4.8 instead of 48.	Ehlert, P.A.I., T.A. van Dijk en O. Oenema, 2016. <i>Inclusion of struvite as a category in the Fertiliser Act; Advice</i> . Wageningen, Statutory Research Tasks Nature & Environment (WOT Natuur & Milieu), WUR, Wageningen. WO technical report 69., http://edepot.wur.nl/394872 Chen, Y., J. Tang, W. Li, Z. Zhong and J. Yin, 2015. Thermal decomposition of magnesium ammonium phosphate and adsorption properties of its pyrolysis products toward ammonia nitrogen. <i>Transactions of the none-ferrous Metals of China</i> . 25(20): 497-503. Ramlogan, M.V.. A.A. Rouff, 2016. An investigation of the thermal behaviour of magnesium ammonium phosphate hexahydrate. <i>Journal of thermal analysis and calorimetry</i> 123: 145-152.

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End-material quality	2.4.3, page 15, lined 540	PFC criteria are applicable on STRUBIAS materials that are used as fertiliser. Secondary raw materials who undergo further processing should not be enforced to meet 'end-material quality conditions'. Clarification is needed. Statement is confusing.		
Pre-treatments	2.4.3.1 pages 15, 16, lines 544-588	Mechanical separation techniques are part of the pre-processing phase. The separation technique effects the quality. The text is fully focussed on municipal waste water treatment plants. It is an omission that other waste water treatments (potato processing plants, manure processing plants) are not mentioned.		
Seed bed	2.4.3.2, page 17, lines 607-609	Struvite fines are most often investigated (Kataki et al, 2016). However poorly soluble Mg-compounds (MgO), stainless steel mesh, pumice stone and borosilicate glass may serve also as seed. MgO acts also as a flocculant.	Kataki et al (2016).	Kataki, Sampriti and West, Helen M. and Clarke, Michèle L. and Baruah, Debendra C. (2016) Phosphorus recovery as struvite: recent concerns for use of seed, alternative Mg source, nitrogen conservation and fertilizer potential. Resources, Conservation and Recycling, 107 . pp. 142-156. ISSN 0921-3449
No constraints	2.4.3.2, page 17, lines 611 - 626	Minerals, ores and ore concentrates are exemptions from the obligation to register in accordance with article 2(7)(b) of 1907/2006. It is advised not to exclude these material as they can contribute to the P recovery process. Potassium based by-products and struvite (seed) are lacking. The chemicals and additives normally do not contribute to an enhancement of the environmental risk of the recovered P salt. The risk can be contributed to waste that is treated. Risk assessment starts with the waste that is treated and thus may require a positive list of wastes that can be used for P recovery.		Annex V of Regulation (EC) 1907/2006.

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		<p>Municipal sewage bears other risks and thus should have an another risk assessment than waste water of potato plants or manure.</p> <p>The identification of the object of risk assessment is: maintaining a high level of protection of human, animal, and plant health, safety and the environment.</p> <p>The constrains that are proposed do not fit well with the assumptions of the new proposal for a fertiliser regulation.</p>		
Post-processing	2.4.3.3, page 17 and 18, lines 628-646.	<p>Post-processing is more than washing or pelletizing. Post-processing can also include chemical reactions (line 645), thermal processing, grinding, re-crystallisation etc. However the interim report is not clear if these processing techniques are allowed for a CMC material.</p> <p>STRUBIAS materials are also serving the production of organic fertilisers and organo-mineral fertilisers and are not only restricted to PFC 1(C)(I)(a)(i-ii)(A).</p>		
Bio-waste	2.4.4, page 18, line 668	<p>These biowastes are <u>designated</u> biowastes from food and feed industry, residues from agriculture and landscape management.</p> <p>The text does not specify food industry. Advice is given to define food industry as food and feed industry to prevent the misunderstanding that feed industry is excluded.</p>		Ehlert, P.A.I, H.J. van Wijnen, J. Struijs, T.A. van Dijk, L. van Schöll & L.R.M. de Poorter (2016). <i>Risk assessment of contaminants in wastes and by-products to be used as co-digestion material</i> . Statutory Research Tasks Unit for Nature & Environment, WUR, Wageningen. WOt-technical report 70. http://edepot.wur.nl/394875
CMC	2.4.4, page 19, line 686	<p>P salts recovered from manure is an animal by-product (manure is an animal by-product category 2 according to 1069/2009 and 142/2011). As such these P salts have to be included in the table of</p>		

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		CMC 11. And this is currently not yet the case.		
Cleaners and detergents	2.4.4, page 19, line 696	Flocculants (e.g. some based on polyacrylamide) are also of concern.		
exclude	2.4.4, page 20, lines 748-749	Advise is given to exclude only industries that can be designated as environmentally hazardous in advance. Current proposal generalises too much.		
169/2009	2.4.4, page 21, line 768	169/2009 ² =1069/2009		
Question	2.4.4, page 21, lines 765-768, 775-779	The criterion ' <i>not having received chemical substances and additives during prior processing steps</i> ' excludes almost all wastes of some major food processing industries. Flocculants, pH regulators, chemical and biological stabilisers are commonly in use to increase the efficiency of removal of fat collected from pits, by flotation from slaughterhouses or the collection of kitchen wastes of restaurants.		
mainly available	2.4.6, page 24, line 878	<p>There is a keen interest to link the content of organic C to the extents P-salt from recovery processes are loaded with contaminants and pathogens. Although the working hypothesis is that there is an positive relation the C content and the levels of contaminants and pathogens, there is no conclusive evidence as far as we know now. Evidence of scientific literature is not coherent.</p> <p>Ye at al (2016) reported in adsorption of tetracyclines by struvite. Their study points out that the occurrence of this pharmaceutical is independent of the content of organic C as tetracyclines in absorbed to the mineral itself. Ke et al (2012) reported tetracycline,</p>		<p>Ye, Zhi-Long, Yujun Deng, Yaoyin Lou, Xin Ye, Jianqiao Zhang and Shaohua Chen, 2016. Adsorption behavior of tetracyclines by struvite particles in the process of phosphorus recovery from synthetic swine wastewater. <i>Chemical Engineering Journal</i>, 313: 1633-1638.</p> <p>Kemacheevakul P., S. Otani, T. Matsuda and Y. Shimizu, 2013. Occurrence of micro-organic pollutants on phosphorus recovery from urine. <i>Water Science & Technology</i>, 66.10, 2191-2201.</p> <p>Butkovskyia, A., L. Hernandez, G. Zeeman, and H.H.M. Rijnaarts, 2017. Micropollutants in source separated wastewater streams and recovered resources of source separated sanitation. <i>Environmental Research</i>, 156, July 2017, 434-442. https://doi.org/10.1016/j.envres.2017.03.044</p>

² 169/2009: Council Regulation (EC) No 169/2009 of 26 February 2009 applying rules of competition to transport by rail, road and inland waterway

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		<p>erythromycin, and norfloxacin remained in the struvite, and, especially, tetracycline remained in struvite with quite a high amount.</p> <p>Pharmaceuticals and personal care and household products (PCPs) tend not to be sorbed to struvite (Butkovskiy et al, 2017).</p> <p>Struvite precipitation is considered to lead to a fertilising product almost free of contaminants and which have a high P availability (Bloem et al, 2017).</p>		<p>Bloem, E., A. Albiñ, J. Elving, L. Hermann, L. Lehmann, M. Sarvi, T. Schaaf, J. Schick, E. Turtola, K. Ylivainio, 2017. Contamination of organic nutrient sources with potentially toxic elements, antibiotics and pathogen microorganisms in relation to P fertilizer potential and treatment options for the production of sustainable fertilizers: A review. Science of the Total Environment 607–608 (2017) 225–242 . http://dx.doi.org/10.1016/j.scitotenv.2017.06.274</p>
Theoretical and experimental evidence	<p>2.4, page 13, lines 435-438</p> <p>Lines 461-464</p> <p>Lines 518-519</p> <p>2.4.6.1, page 24, lines 889-909</p>	<p>STOWA (2015) reports the results of three struvite production locations (samples not washed and washed). Removal of debris (twigs, seeds) lowered concentrations of organic contaminants which are not designated by the Fertiliser Act of the Netherlands in struvite samples originated from municipal waste water treatment plants. Sample material fulfilled requirements for organic contaminants designated by the Fertiliser Act of the Netherlands.</p> <p>These results cannot be generalised to struvite from e.g. potato processing plants of manure processing plants. The presence of contaminants in P-salts, either organic or inorganic, depends on both the source material and the processing and is only partially related to the presence of organic material in the source material.</p> <p>Literature is limited and not supporting a general conclusion on a criterion on organic C although the working hypothesis (see given comment line 878) assumes that there is a positive relationship.</p>		

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Question	2.4.6.1, page 25, lines 939-943	See literature of Table 1 and Table 3 of Ehlert et al (2016)		Ehlert, P.A.I., T.A. van Dijk en O. Oenema, 2016. <i>Inclusion of struvite as a category in the Fertiliser Act; Advice</i> . Wageningen, Statutory Research Tasks Nature & Environment (WOT Natuur & Milieu), WUR, Wageningen. WOt technical report 69., http://edepot.wur.nl/394872
Risk assessment	2.4.6.1., page 26, lines 962-964	This statement needs to be more precise. When referring to persistent organic pollutants this may be true since these are phased out during the last decades. It seems not true for other organic contaminants including human medicinal compounds or 'new' organic contaminants including PFOA's etc.		
"it is concluded that pharmaceuticals..."	2.4.6.1, page 28, lines 1040	On page 28, lines 1064-1067 the report states that: "it is concluded that pharmaceuticals [...] for which reason there is no major risk in terms of safety [...] for the environment or the food chain." This suggests that the authors have assessed the risk of found concentrations of pharmaceuticals in struvite for environmental endpoints or food uptake. However, no supporting evidence is provided. Further corroboration on how the risk of pharmaceuticals is assessed, including assumptions about fate, exposure and uptake, is needed.		Van der Grinten, E. en Spijker, J. 2017. Medicijnresten, pathogenen en antibiotica resistentie in struviet; Eerste resultaten voor struviet uit Nederlands huishoudelijk afvalwater. RIVM briefrapport nr 2017-0144, in prep. Van der Grinten, E. and Spijker, J. 2017. Pharmaceutical residues, pathogens, and antibiotic resistance in struvite; First results for struvite from Dutch Municipal waste water. RIVM letter report nr 2017-0144, in prep.
Washing procedure	2.4.6.1, page 28, lines 1073-1074	On page 28, lines 1073 - 1074, considering the washing procedure, this washing procedure was based on a laboratory test and hand picking, and does not reflect current practice.		Van der Grinten, E. en Spijker, J. 2017. Medicijnresten, pathogenen en antibiotica resistentie in struviet; Eerste resultaten voor struviet uit Nederlands huishoudelijk afvalwater. RIVM briefrapport nr 2017-0144, in prep. Van der Grinten, E. and Spijker, J. 2017. Pharmaceutical residues, pathogens, and antibiotic resistance in struvite; First results for struvite from

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
				Dutch Municipal waste water.RIVM letter report nr 2017-0144, in prep.
Monitor Salmonella and E. coli	Lines 1082-1089	On page 29, lines 1082 - 1089 it is proposed to monitor Salmonella and E. coli, although these bacteria are expected to die off under the conditions that struvite is produced (STOWA 2015). Spore forming bacteria are not mentioned, despite their presence in struvite, even after the washing procedure, according to STOWA (2015). Pharmaceuticals are not mentioned for monitoring, despite several reports of their presence in struvite. Monitoring of spore forming bacteria and pharmaceuticals is not necessary, but only after providing sound evidence that there is no risk associated with these contaminants.		<p>Van der Grinten, E. en Spijker, J. 2017. Medicijnresten, pathogenen en antibiotica resistentie in struviet; Eerste resultaten voor struviet uit Nederlands huishoudelijk afvalwater. RIVM briefrapport nr 2017-0144, in prep.</p> <p>Van der Grinten, E. and Spijker, J. 2017. Pharmaceutical residues, pathogens, and antibiotic resistance in struvite; First results for struvite from Dutch Municipal waste water.RIVM letter report nr 2017-0144, in prep.</p>
Data on organic micropollutants	2.4.6.1, page 28, lines 1036-1039	The study reports on <u>designated</u> biowastes from food and feed industry, residues from agriculture and landscape management.		Ehlert, P.A.I, H.J. van Wijnen, J. Struijs, T.A. van Dijk, L. van Schöll & L.R.M. de Poorter (2016). <i>Risk assessment of contaminants in wastes and by-products to be used as co-digestion material</i> . Statutory Research Tasks Unit for Nature & Environment, WUR, Wageningen. WOt-technical report 70. http://edepot.wur.nl/394875
Question	2.4.6.1, page 29, lines 1091-1100	<p>Information on PAH is indeed limited. Data of Montag et al (2009) show low values for PAH concentrations in P salts (designated as struvite). Montag et al (2009) reports average values for ΣPAH10 (EU) < 0,254 mg/kg dry matter and for ΣPAH 16 (EPA) < 0,390 mg/kg dry matter for struvite samples with an average of 226,7 g P₂O₅/kg dry matter.</p> <p>Gell et al. (2011) concluded on the basis of literature on urine composition that (amongst others) PAH in struvite from communal waste water is negligible low.</p>		<p>Montag, D., K. Gethke, W. Everding en J. Pinnekamp, 2009. Nährstoff- und Schadstoffgehalte in Sekundärphosphaten. GWA Band 217, 42. Essener Tagung für Wasser- und Abfallwirtschaft, Gesellschaft zur Förderung der Siedlungswasserwirtschaft an der RWTH Aachen e.V., Aachen 2009, ISBN 978-3-938996-23-2</p> <p>Gell, K., F.J. de Ruijter, P. Kuntke, M. de Graaff en A.L. Smit, 2011. Safety and effectiveness of struvite from black water and urine as a phosphorus fertilizer. Journal of Agricultural Science 3(3): 67-80 http://edepot.wur.nl/177913</p>

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
Input materials	2.4.6.2, page 29, lines 1115-1116	The concentration of metals in municipal waste water also varies depending on sources or industries present. Also levels of metals/micronutrients like Cu and Zn can be even higher in animal manure due to additions to feed and drinking water (e.g. Römken and Rietra, 2008)		Römken, P.F.A.M. and R.P.J.J. Rietra. 2008. Zware metalen en nutriënten in dierlijke mest in 2008. Gehalten aan Cd, Cr, Cu, Hg, Ni, Pb, Zn, As, N en P in runder-, varkens- en kippenmest. Alterra rapport 1729, Alterra, Wageningen. http://edepot.wur.nl/2536
Reducing Cd contamination	2.4.6.2, page 30, lines 1141-1142	Speculative, changes in soil Cd are very small even after 100 yrs (Smolders, 2017). Aside from this, the changes in soil Cd strongly depend on soil properties and in most arable soils with pH > 6 (containing lime or high clay content) most of the Cd added to soils will remain in the soil due to the limited solubility under such conditions		Smolders, E. 2017. Scientific aspects underlying the regulatory framework in the area of fertilisers – state of play and future reforms. In-depth analysis for the IMCO committee. IP/A/IMCO/2016-19. PE 595.354. European Union, 2017.
Stored in dry conditions	page 30, 2.4.6.3, lines 1150-1152	If a P salt is directly used as fertilising material (and thus meet the requirements of the PFC (solid of liquid)) application as a liquid slurry serves agronomic use. Alternative: The fertilising product is uniform in composition and fit for practical use.		
Granulometry	Page 31, 2.4.7.3., lines 1166-1180	These conditions serve PFC.		
Same criteria	Page 33, 2.4.8, lines 1250-1251	Direct use requires that a CMC material meets the requirements of a PFC. If a CMC material is processed first, than there is no need for the application of the criteria of a PFC on this material.		
Question	2.4.8, page 33, lines 1253-1275	Chemical substances used during possible post-processing of recovered phosphates are often REACH registrated. Exemptions are: - substances that fulfil conditions of Annex V (exempted from registration, e.g. molasses);		

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
		<p>- substances that are not recognised as chemical substances;</p> <p>Post-processing of P-salts currently leads to mineral fertilisers. Substances for the production of mineral fertilisers have a registration in REACH.</p>		
Question	2.5.3.2., page 38, Core process	The new fertiliser regulation is a generic regulation. Process conditions (not linked to sanitation) are not part of a generic regulation. If the CMC's for STRUBIAS materials have criterions on process conditions, this would reverse the process of simplifying the regulation on fertiliser products. Also the current EU fertiliser regulation 2003/2003 with elaborate fertiliser type designation gives no information on the conditions of the production process.		
Environmental aspects	2.5.6., page 46, lines 1781 onwards	Aside from the general comments related to the use of the model the approach followed here does not consider the impact of ashes on soil as such. In many cases, certainly for fly ash, pH is very high (> 9) which can result in a significant short and medium term (days-weeks) impact on soil pH (e.g. Cruz et al., 2017). This shift in pH can result in a marked release of a.o. dissolved organic carbon and metalloids like As and Se which become more mobile at high pH.		Cruz, N.C., Rodrigues, S.M., Carvalho, L., Duarte, A.C., Pereira, E., Römkens, P.F.A.M., Tarelho, L.A.C. 2017. Ashes from fluidized bed combustion of residual forest biomass: recycling to soil as a viable management option. Environmental Science and Pollution Research, 24 (17), pp. 14770-14781.
Aluminum, iron and manganese	2.5.6.1.,page 47, lines 1809 onwards	This discussion on Al, Fe and Mn seems imbalanced in relation to that of other contaminants. Specifically for Al: Al solubility also increases in systems with pH > 8 due to the formation of soluble Al(OH) ₄ ⁻ complexes (e.g. McBride, 1994) and considering the high pH of a large part of ashes produced this is a point of concern as well (see previous remark on short term impact on soil)		McBride, M.B. 1994. Environmental Chemistry of Soils. Oxford University Press

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
aluminum	2.5.6.1., page 47, lines 1821-1822	Al solubility also increases at high pH (McBride, 1994) which prevails in many ashes and, for shorter or longer periods also in soil.		McBride, M.B. 1994. Environmental Chemistry of Soils. Oxford University Press
Mn toxicity	2.5.6.1., page 48, lines 1853-1855	In most soils combinations of redox potential and pH are such that Mn is not toxic and, at near neutral conditions mostly in a solid form (MnO ₂). Mn toxicity is related to the speciation in solution and under normal soil condition most Mn is in a non-toxic or form or in non-toxic concentrations (if in solution). Only under water logged conditions solubility of Mn can increase to such an extent that concentrations may become toxic (McBride, 1994). To compare toxic effect levels as observed in test conditions with levels in soils is therefore partly misleading. The same can be stated for most other metals as well when considering toxic effects in solution which then can be recalculated to extremely low concentrations in soils as well		McBride, M.B. 1994. Environmental Chemistry of Soils. Oxford University Press
Earthworm avoidance test	2.5.6.1., page 48, lines 1878-1880	The earthworm avoidance test is used as a rapid screening method for evaluating the habitat function of soils and the effect of chemicals on earthworm behaviour. It is however questionable if ashes in general will lead to a positive result. Presence of oxides and hydroxides in ashes will lead to an avoidance of soil treated with this material and this avoidance is not a result of a contaminant but from the oxides and hydroxides. Moreover, Mn in an ash will converted in soil to MnO ₂ . Therefore an avoidance of an earthworm cannot be interpreted as an result of the occurrence if Mn only but effects of the presence of CaO and/or Ca(OH) ₂ have also be taken into account. Both CaO and Ca(OH) ₂ are currently liming materials that can fulfil		ISO 17512-1:2008. Soil quality -- Avoidance test for determining the quality of soils and effects of chemicals on behaviour -- Part 1: Test with earthworms (<i>Eisenia fetida</i> and <i>Eisenia andrei</i>) ISO 17512-2:2011 Soil quality -- Avoidance test for determining the quality of soils and effects of chemicals on behaviour -- Part 2: Test with collembolans (<i>Folsomia candida</i>) Demuyneck, S., L.R. Succiu and F. Grumiaux, Fabien, 2014. Effects of field metal-contaminated soils submitted to phytostabilisation and fly ash-aided phytostabilisation on the avoidance behaviour of the earthworm <i>Eisenia fetida</i> . Ecotoxicology and environmental safety 107: 170-177.

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
		requirements of the current fertiliser regulation (2003/2003; 463/2013).		Kobeticova, K., J. Hofman and I. Holoubek, 2010. Ecotoxicity of wastes in avoidance tests with <i>Enchytraeus albidus</i> , <i>Enchytraeus crypticus</i> and <i>Eisenia fetida</i> (Oligochaeta). Waste management 30 (4) 558-564.
Relatively small additions	2.5.6.1., page 50, lines 1905-1907	Statements are quite vague: 'relatively small additions', 'high soil concentrations', 'over time'. This suggests that any addition even if very low (whatever low is....) results in accumulation. This is not true and depends entirely on the balance between inputs, outputs which then partly depend on soil conditions (both leaching and plant uptake are strongly related to a.o. pH, organic matter etc. see a.o. De Vries and McLaughlin, 2013).	Relatively small additions	De Vries, W. & McLaughlin, M. J. 2013. Modeling the cadmium balance in Australian agricultural systems in view of potential impacts on food and water quality. Science of the Total Environment, 461-462, 240-257.
Box 1. Risk assessment procedure	2.5.6.1., pages 51-56	The definition of risks remains unclear or confusing: many of the risk limits discussed (but not all) refer to soil clean-up values. Such levels clearly are not relevant for agriculture since the main risk in such systems should be the quality of food and feed products as well as a generic levels of protection of the ecosystem (both in soil and adjacent compartment like surface waters)		EFSA 2009. European Food Safety Authority. Cadmium in food - Scientific opinion of the Panel on Contaminants in the Food Chain. EFSA Journal, 7, n/a-n/a. EFSA 2012. European Food Safety Authority. Cadmium dietary exposure in the European population. EFSA Journal, 10, n/a-n/a. Links to information on Dutch soil policy and current soil quality standards: Soil Clean-up values ('Interventiewaarden'): http://wetten.overheid.nl/BWBR0033592/2013-07-01#Bijlage1 Function specific target values ('Maximale Waarden'): http://wetten.overheid.nl/BWBR0023085/2014-04-01#BijlageB
Box 1, high end assumptions	2.5.6.1., page 53, lines 2005-2007	It is unclear why the assumptions made would result in a protective limit		

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
Box 1, information on the Netherlands	2.5.6.1., page 53, lines 2013-2014	The policy of the Netherlands has been changed considerably and the info provided is partly based on outdated numbers. For a recent overview of approaches used in Dutch Risk Assessment protocols and an overview of relevant soil quality criteria we refer to the annexes in current legislation of the Netherlands (regarding Soil Clean-up Values and function specific acceptable levels, so-called "maximale waarden") or a summary of the main principles (Wezenbeek, 2007, Dirven-Van Breemen et al, 2008)		<p>Wezenbeek, J.M. 2007. Know the quality of your soil or aquatic sediment: clarifying the risks. SenterNovem report 3BODM0704 http://rwsenvironment.eu/subjects/soil/publications/know-the-quality/</p> <p>Dirven-Van Breemen E.M., J.P.A. Lijzen, P.F. Otte, P.L.A. van Vlaardingen, J. Spijker, E.M.J. Verbruggen, F.A. Swartjes, J.E. Groenenberg, M. Rutgers, 2008. Landelijke referentiewaarden ter onderbouwing van maximale waarden in het bodembeleid, RIVM rapport 711701053, Bilthoven http://www.rivm.nl/dsresource?objectid=440ace92-3307-4f80-a1d7-ad710a83c4c6&type=org&disposition=inline see table 6, page 40.</p>
Table 4	2.5.6.1., page 53, table 4, lines 2005-2007	Part of the data seem incorrect, in the NL we have no standards for Se and V for example. See Dirven-Van Breemen et al, 2008		<p>Dirven-Van Breemen E.M., J.P.A. Lijzen, P.F. Otte, P.L.A. van Vlaardingen, J. Spijker, E.M.J. Verbruggen, F.A. Swartjes, J.E. Groenenberg, M. Rutgers, 2008. Landelijke referentiewaarden ter onderbouwing van maximale waarden in het bodembeleid, RIVM rapport 711701053, Bilthoven http://www.rivm.nl/dsresource?objectid=440ace92-3307-4f80-a1d7-ad710a83c4c6&type=org&disposition=inline see table 6, page 40.</p>
Table 5	2.5.6.1., page 54, table 5, lines 2048-2050	At present a more representative data collection is available for this purpose specifically addressing arable soils: GEMAS database (Reimann et al., 2014)		<p>Reimann, C., M. Birke, A. Demetriades, P. Filzmoser and P. O'Connor (eds). 2014. Chemistry of Europe's Agricultural Soils Part A and B. Geologisches Jahrbuch, Reihe B, Heft 102, 103. Hannover.</p>
Liquid-solid partition coefficients	2.5.6.1., page 55, lines 2075-2076	The use of a constant linear K _d to model sorption of metals and metalloids is flawed since K _d values are extremely variable as a result of the impact of a.o. pH, organic matter and to some extent clay and oxides on the retention of metals in soils (see a.o. Table 11.1 and 11.2 in Reimann et al. 2014; GEMAS database). The source database (Sheppard et al. 2009) only contains 7 soils and most of them being rather acid soils (6 out of 7 have a pH		<p>Reimann, C., M. Birke, A. Demetriades, P. Filzmoser and P. O'Connor (eds). 2014. Chemistry of Europe's Agricultural Soils Part A and B. Geologisches Jahrbuch, Reihe B, Heft 102, 103. Hannover.</p> <p>Sheppard S., Long J., Sanipelli B. & Sohlenius G. (2009) Solid/liquid partition coefficients 4879 (K_d) for selected soils and sediments at Forsmark and Laxemar-Simpevarp. SKB 4880 Rapport R-09-27. Swedish Nuclear Fuel</p>

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
		<p>equal to or below 5) and are hence not representative for the majority of arable soils in the EU (average pH-CaCl₂ 6.2) since the K_d can be expected to be lower (higher mobility) compared to that in soils with a higher pH as was in fact documented by Sheppard (2011) in a later paper. A more comprehensive range of K_d values specifically for arable (and grassland) soils is given in the GEMAS Atlas from Europe and shows that for most metals a range of several orders of magnitude can be found depending on the metal of interest. Given the fact that retention (K_d) is one of the key parameters that controls the magnitude of the proposed limit values a more in depth analyses is required before any recommended level for metals in ashes (or biochar) can be derived when using this approach. We suggest to use the range in K_d value for European soil to derive an acceptable load of the soil. Wageningen UR has the tools to support JRC in this type of risk assessment.</p>		<p>Sheppard, S. C. 2011. Robust Prediction of K_d from Soil Properties for Environmental Assessment, Human and Ecological Risk Assessment: An International Journal, 17:1, 263-279.</p>
500 mm per year	2.5.6.1., page 55, line 2078	<p>It is not the amount of precipitation that is needed in the calculation but rather the amount of water leaching from the soil, i.e. precipitation minus evapotranspiration. This reduces the net leaching flux by almost 50%, which is in line with estimates made by e.g. Velthof et al. (2009) and Six and Smolders (2014) who applied values between 50 and 300 mm year⁻¹. This means that less metals are lost and hence, critical application rates will be lower than the ones presented in table 7.</p>		<p>Six, L., Smolders, E. 2014. Future trends in soil cadmium concentration under current cadmium fluxes to European agricultural soils. Science of the Total Environment, 485-486 (1), pp. 319-328.</p> <p>Velthof, G.L., Oudendag, D., Witzke, H.P., Asman, W.A.H., Klimont, Z., Oenema, O. 2009. Integrated assessment of nitrogen losses from agriculture in EU-27 using MITERRA-EUROPE. Journal of Environmental Quality, 38 (2), pp. 402-417.</p>
Crop uptake	2.5.6.1., page 56	Crop uptake is not considered at all in the equation?		

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
Niu et al, 2016	2.5.6.1., page 58, table 8	Reference lacks		
Leaching test	2.5.6.1., page 59, lines 2177-2179	Leaching of metals from ashes or fly ash treated soils is a major issue for specific elements like As and Se, as has been documented both in the low (pH < 4) and high pH range (pH > 7; e.g. Komonweeraket et al., 2015). Again, leaching of contaminants strongly depends on soil conditions and changes in soil pH brought forth by the use of ashes may result in the release of soil bound contaminants without even considering additional inputs. Mobilisation of As from ashes in pasture soils was shown to result in increased leaching rates and even increased levels in fodder crops (ryegrass; Mollon et al., 2016).		<p>Komonweeraket, K., Cetin, B., Benson, C.H., Aydilek, A.H., Edil, T.B. 2015. Leaching characteristics of toxic constituents from coal fly ash mixed soils under the influence of pH. Waste Management, 38 (1), pp. 174-184.</p> <p>Mollon, L.C., Norton, G.J., Trakal, L., Moreno-Jimenez, E., Elouali, F.Z., Hough, R.L., Beesley, L. 2016. Mobility and toxicity of heavy metal(loid)s arising from contaminated wood ash application to a pasture grassland soil. Environmental Pollution, 218, pp. 419-427.</p>
Linear relationship Kd	2.5.6.1., page 59, lines 2181-2183	The assumption of a linear relationship (Kd) between contaminants in the solid phase and solution is not necessarily valid under all conditions and depends on both concentration ranges and soil type. In non-polluted soils at low solution concentration levels, strongly non-linear relations have been obtained between soil metal content and dissolved metal concentrations (e.g. Groenenberg et al. 2012). Furthermore, even in those conditions where a linear Kd appears to be applicable, the Kd, e.g. for Cd still strongly depends on soil properties like pH, organic matter (e.g. de Vries et al., 2011). Also, under equilibrium conditions where precipitation control the solubility, the concentration in solution is also not related to the total amount stored in soil but rather constant.		<p>De Vries, W., M.J. McLaughlin, J.E. Groenenberg. 2011. Transfer functions for solid-solution partitioning of cadmium for Australian soils, Environmental Pollution, Volume 159, Issue 12, 2011, Pages 3583-3594.</p> <p>Groenenberg, J.E., Dijkstra, J.J., Bonten, L.T.C., De Vries, W., Comans, R.N.J. 2012. Evaluation of the performance and limitations of empirical partition-relations and process based multisurface models to predict trace element solubility in soils. Environmental Pollution, 166, pp. 98-107.</p>

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
Linear relationship Kd	2.5.6.1., page 59, lines 2187-2189	Considering the previous remarks this statement seems not valid under all conditions		
Question	2.5.6.2, page 61, lines 2270-2279	<p>Information on contaminants in ashes is (very) limited.</p> <p>Data on contaminants in ashes from sewage sludge are given by Koornneef et al 2005, De Graaf et al, 2017 and Krüger et al, 2014). Jan Evert van Veldhoven (for EurEau) has uploaded in November 2016 on CIRCABC on composition of ashes of sewage sludge.</p> <p>Data sets on contaminants in hydrated poultry litter ash are given in Annex 4</p>		<p>De Graaff, Lonneke, Ingrid Odegard en Sanne Nusselder, 2017. LCA thermische conversie pluimveemest BMC Moerdijk <i>CE Delft, maart 2017</i>, Publicatienummer: 17.2H94.01 versie 2. http://www.ce.nl/publicatie/lca_thermische_conversie_pluimveemest_bmc_moerdijk/1933</p> <p>Koornneef, J.M. Janus and D. Berkhof, 2005. Wat te doen met zuiveringsslib? Studie naar het nuttig toepassen van slib of haar residuen als bouwstof. STOWA rapportnummer 2005-27. ISBN 90.5773.315.3. http://edepot.wur.nl/118864</p> <p>Krüger, O., A. Grabner and C. Adam, 2014. Complete survey of German sewage sludge ash. <i>Environmental Science & Technology</i> 48: 11811-11818, dx.doi.org/10.1021/es502766x</p> <p>Annex 4: Table 4.1. Specification hydrated poultry litters ash</p> <p>Annex 4: Table 4.2. Dioxins in hydrated poultry litter ash in the period 2012-2014.</p> <p>Source: Technical dossier of hydrated poultry litter ash for its inclusion as PK fertiliser in Annex I of Regulation (EC) No 2003/2003</p>
2.6.6. Environmental	2.6.6 onwards, page 83, line 3087	In general the remarks as stated under ashes are applicable for biochar as well. It remains questionable whether metals added via ashes or biochar behave as if they were in equilibrium with the soil (as is assumed since a soil derived Kd is being used) or that the mobility is reduced		

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
		resulting in a stronger accumulation in soil compared to metals added in a more available form.		
Question	2.6.6.1, page 86, lines 3201-3208	Data on contaminants in pyrolysis materials are scarce. Publications are given which provides some data.		<p>Inyang, M.I., B. Gao, Y. Yao, Y. Xue, A. Zimmerman, A. Mosa, P. Pullammanappallil, Y. S. Ok and X. Cao, 2016. A review of biochar as a low-cost adsorbent for aqueous heavy metal removal. <i>Critical Reviews in Environmental Science and Technology</i>. 46, (4): 406-433. http://dx.doi.org/10.1080/10643389.2015.1096880</p> <p>Rizwan Muhammad, Shafaqat Ali, Muhammad Farooq Qayyum, Muhammad Ibrahim, Muhammad Zia-ur-Rehman, Tahir Abbas and Yong Sik Ok, 2015. Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: a critical review. <i>Environ Sci Pollut Res</i> (2016) 23:2230–2248. DOI 10.1007/s11356-015-5697-7.</p> <p>Hartley, W., Dickinson, N.M., Riby, P., and Lepp, N.W., 2009. Arsenic mobility in brownfield soils amended with green waste compost or biochar and planted with <i>Miscanthus</i>. <i>Environ. Pollut.</i> 157, 2654.</p> <p>Lilian Marchand, Céline Pelosi, María Reyes González-Centeno, Anne Maillard, Alain Ourry, William Galland, Pierre-Louis Teissedre, Jean-Jacques Bessoule, Sébastien Mongrand, Annette Morvan-Bertrand, Qinzhong Zhang, Claire Grosbellet, Valérie Bert, Nadège Oustrière, Michel Mench, Sophie Brunel-Muguet. 2016. Trace element bioavailability, yield and seed quality of rapeseed (<i>Brassica napus</i> L.) modulated by biochar incorporation into a contaminated technosol. <i>Chemosphere</i> 156, 150-162.</p> <p>Wolfram Buss, Margaret C. Graham, Jessica G. Shepherd, Ondřej Mašek. 2016. Suitability of marginal biomass-derived biochars for soil amendment. <i>Science of The Total Environment</i> 547, 314-322.</p>

Observation	Location in document	Correction/alternative proposal	Techno-scientific rationale that supports the comment raised	Reference to techno-scientific data
				Michael W.H. Evangelou, Anette Brem, Fabio Ugolini, Samuel Abiven, Rainer Schulin. 2014. Soil application of biochar produced from biomass grown on trace element contaminated land. <i>Journal of Environmental Management</i> 146, 100-106.
Question	2.6.6.2, page 88, lines 3263-3271	Data for biochar of co-digested pig manure from pyrolysis at different temperature and oxygen conditions are given in annex 5.		Annex 5 Source: Ehlert, P.A.I et al (in prep.).
Question Incorrect or obsolete techno-scientific information	5.3, page 117, lines 4087-4097	This review signalise when incorrect and obsolete information. Corrections and alternatives are proposed, see this review.		
Question Market assessment	5.3, pages 118, lines 4100-4115	<p>In the Netherlands total estimated volumes of the STRUBIAS materials are:</p> <p>P-salts: actual production 4628 ton/year with 742 ton P/year; planned capacity 4628 ton/year with 742 ton P/year.</p> <p>Ashes: Actual production of hydrated poultry litter ash is 60 kton/year.</p> <p>Actual production of ashes from sewage sludge is 102.3 kton/year. From this 60 kton will be processed in near future by Ecophos (Dunkirk).</p> <p>Chars are produced in the Netherlands. These chars serve as fuels. Biochar (char used as soil amendment) production has not entered a production phase coupled with a market yet.</p>		

Annex 1. Proposed extractants for STRUBIAS materials

General literature

Cabeza, R., B. Steingrobe, W. Römer and N. Claassen, 2011. Effectiveness of recycled P products as P fertilizers, as evaluated in pot experiments. *Nutr Cycl Agroecosyst* 91:173–184. DOI 10.1007/s10705-011-9454-0

Kratz, S., Judith Schick and Anne Falk Øgaard, 2016. P Sources. P Solubility of Inorganic and Organic. Pp 127-152. In: Schnug & De Kok, 2016)

Krüger, O. and Ch. Adam, 2017. Phosphorus in recycling fertilizers - analytical challenges. *Environmental Research* 155 (2017) 353–358.

Schnug, E. & Luit J. De Kok, Editors. *Phosphorus in Agriculture: 100 % Zero*. Springer. ISBN 978-94-017-7611-0 ISBN 978-94-017-7612-7 (eBook) DOI 10.1007/978-94-017-7612-7

Severin, M., J. Breuer, M. Rex, J. Stemann, Ch. Adam, H. Van den Weghe and M. Kücke, 2014. Phosphate fertilizer value of heat treated sewage sludge ash. *Plant Soil Environ.* 60, No. 12: 555–561

For relevance for organic farming see:

FIBL, Research institute for organic farming, 2016. Chars, ashes and slags. Assessment of recycled phosphorus for organic farming. ISBN-PDF 978-3-03736-344-7

STRUBIAS material	Compared extractants	Proposed extractant	Reference
High ash biochars	NAC, CA, FA	FA	Wang Tao Camps-Arbestain, M. Hedley, M. Bishop, P. 2012. Predicting phosphorus bioavailability from high-ash biochars. <i>Plant and Soil</i> , . 357(1/2):173-187.
P-recycling fertilizers	MA, NAC+W, NAC, CA, AAC, FA	NAC	Kratz, S. Haneklaus, S. Schnug, E., 2010. Chemical solubility and agricultural performance of P-containing recycling fertilizers. <i>Landbauforschung Volkenrode</i> ; 2010. 60(4):227-240.
Untreated gasifier ash Lime free gasifier ash	MA, NAC, AAC, FA	CA>NAC>AAS CA>AAS>NAC No advice was given	Ksawery, K. John, G. R. Gorm, P. T. Emielda, Y. B., 2010. The composition and dissolution in citric extractants of ash from the thermal gasification of pig manure. <i>Chemical Engineering Journal</i> ; 163(1/2):1-9.
Ashes	MA, NAC, CA, AAC, FA and iron bag (IB)	CA based extractants had no relation with P availability for crop	Yusiharni, B. E. Ziadi, H. Gilkes, R. J. 2007. A laboratory and glasshouse evaluation of chicken litter ash, wood ash, and iron smelting slag as liming agents and P fertilisers. <i>Australian Journal of Soil Research</i> ; 2007. 45(5):374-389.
Biosolids (sewage sludge)	MA, NAC	NAC had no relation with P plant availability	Elliot, H. A. Potter, J. M. Kang, J. H. Brandt, R. C. O'Connor, G. A., 2005. Neutral ammonium citrate extraction of biosolids phosphorus. <i>Communications in Soil Science and Plant Analysis</i> ; 36(17/18):2447-2459. 29 ref.
Rock phosphates	NAC, CA, FA	NAC>CA>FA	Zaharah, A. R. Zulkifli, H. Sharifuddin, H. A. H., 1996. Evaluating the efficacy of various phosphate fertiliser sources for oil palm seedlings. 1996/1997. <i>Nutrient Cycling in Agroecosystems</i> ; 47(2):93-98. 20 ref.

STRUBIAS material	Compared extractants	Proposed extractant	Reference
Various incl. struvites and ashes	MA, CA, W, isotopically exchangeable P (IEP)	IEP	Cabeza, R., B. Steingrobe, W. Römer and N. Claassen, 2011. Effectiveness of recycled P products as P fertilizers, as evaluated in pot experiments. <i>Nutr Cycl Agroecosyst</i> 91:173–184. DOI 10.1007/s10705-011-9454-0

Annex 2. P-salts that are registered in REACH and can serve as a material for fertiliser production.

Name	Public name	EC / List Number	Cas Number	Registration Type	Submission Type	Total tonnage Band	Factsheet URL	Substance Information Page
dicalcium didihydrogen phosphate hydrogen phosphate		914-172-8	-	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/10748	https://echa.europa.eu/substance-information/-/substanceinfo/100.144.083
Dicalcium pyrophosphate		232-221-5	7790-76-3	Intermediate	Joint	Intermediate Use Only	https://echa.europa.eu/registration-dossier/-/registered-dossier/12520	https://echa.europa.eu/substance-information/-/substanceinfo/100.029.292
Dipotassium hydrogenorthophosphate		231-834-5	7758-11-4	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/14877	https://echa.europa.eu/substance-information/-/substanceinfo/100.028.940
Pentapotassium triphosphate		237-574-9	13845-36-8	Full	Joint	10000 - 100000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/14408	https://echa.europa.eu/substance-information/-/substanceinfo/100.034.145
Potassium pentahydrogen bis(phosphate)		238-961-5	14887-42-4	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/2187	https://echa.europa.eu/substance-information/-/substanceinfo/100.035.404
Reaction mass of ammonium dihydrogenorthophosphate and diammonium hydrogenorthophosphate		913-888-8	-	Full	Joint	100000 - 1000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/13460	https://echa.europa.eu/substance-information/-/substanceinfo/100.138.838
Reaction mass of disodium hydrogenorthophosphate and sodium dihydrogenorthophosphate		913-413-4	-	Intermediate	Joint	Intermediate Use Only	https://echa.europa.eu/registration-dossier/-/registered-dossier/11353	https://echa.europa.eu/substance-information/-/substanceinfo/100.134.576
Reaction products of phosphoric acid, rock phosphate and humic acids, potassium salts		938-988-9	-	Full	Joint	10000 - 100000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/10794	https://echa.europa.eu/substance-information/-/substanceinfo/100.223.382
Reaction products of sulphuric acid, rock phosphate and humic acids, potassium salts		938-989-4	-	Full	Joint	10000 - 100000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/13846	https://echa.europa.eu/substance-information/-/substanceinfo/100.223.381

Superphosphates	Substance obtained by treating phosphate rock with sulfuric acid or a mixture of sulfuric and phosphoric acids. Composed primarily of calcium phosphates and calcium sulfate.	232-379-5	8011-76-5	Full	Joint	1000000 - 10000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15479	https://echa.europa.eu/substance-information/-/substanceinfo/100.029.433
Superphosphates, concd.	Substance obtained by acidulating phosphate rock with phosphoric acid. Normally characterized as containing 40% or more available phosphoric oxide (P ₂ O ₅). Composed primarily of calcium phosphate.	266-030-3	65996-95-4	Full	Joint	100000 - 1000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15391	https://echa.europa.eu/substance-information/-/substanceinfo/100.060.009
Tripotassium orthophosphate		231-907-1	7778-53-2	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/14686	https://echa.europa.eu/substance-information/-/substanceinfo/100.029.006
Urea phosphate		225-464-3	4861-19-2	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/14154	https://echa.europa.eu/substance-information/-/substanceinfo/100.023.149
Polyphosphoric acids, ammonium salts	IUPAC name: Ammonium polyphosphate	269-789-9	68333-79-9	Full	Joint	10000 - 100000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/11698	https://echa.europa.eu/substance-information/-/substanceinfo/100.063.425

Ammonium nitrate	Public name: NPK Nitrogen Phosphor Potassium-complex fertilizers (multi constituent substance of ammonium dihydrogen-ortho-phosphate and ammonium nitrate and ammonium sulphate and potassium chloride natural)	229-347-8	6484-52-2	Full	Joint	10000000 - 100000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15999	https://echa.europa.eu/substance-information/-/substanceinfo/100.026.680
Ammonium sulphate	Public name: NPK Nitrogen Phosphor Potassiumcomplex fertilizers (multi constituent substance of ammonium dihydrogenortho-phosphate and ammonium nitrate and ammonium sulphate and potassium chloride natural)	231-984-1	7704-34-9, 7783-20-2	Full	Joint	1000000 - 10000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15571	https://echa.europa.eu/substance-information/-/substanceinfo/100.029.076
Urea	Public name: urea and NPK fertilizer mult-constituent substance of	200-315-5	57-13-6	Full	Joint	10000000 - 100000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/16152	https://echa.europa.eu/substance-information/-/substanceinfo/100.000.286

	urea and ammonium dihydrogenorth o-phosphate and potassium dihydrogenorth o-phosphate							
Orthophosphoric acid	Trade name: - Orthophosphate	231-633-2	7664-38-2	Full	Joint	1000000 - 10000000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15531	https://echa.europa.eu/substance-information/-/substanceinfo/100.028.758
Orthophosphoric acid	Trade name: - Orthophosphate	231-633-2	7664-38-2	Intermediate	Individual	Intermediate Use Only	https://echa.europa.eu/registration-dossier/-/registered-dossier/16672	https://echa.europa.eu/substance-information/-/substanceinfo/100.028.758

Annex 3. Iron and aluminium phosphate registered in REACH

Name	Public name	EC / List Number	Cas Number	Registration Type	Submission Type	Total tonnage Band	Factsheet URL	Substance Information Page
Aluminium dihydrogen triphosphate		237-714-9	13939-25-8	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/14476	https://echa.europa.eu/substance-information/-/substanceinfo/100.034.272
Aluminium metaphosphate		237-415-3	13776-88-0	Full	Joint	100 - 1000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/5484	https://echa.europa.eu/substance-information/-/substanceinfo/100.034.000
Aluminium orthophosphate		232-056-9	7784-30-7	Full	Joint	1000+ tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15223	https://echa.europa.eu/substance-information/-/substanceinfo/100.029.142
Aluminium tris(dihydrogen phosphate)		236-875-2	13530-50-2	Full	Joint	1000 - 10000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/15100	https://echa.europa.eu/substance-information/-/substanceinfo/100.033.508
Iron orthophosphate		233-149-7	10045-86-0	Full	Joint	100 - 1000 tonnes per annum	https://echa.europa.eu/registration-dossier/-/registered-dossier/13292	https://echa.europa.eu/substance-information/-/substanceinfo/100.030.123

Annex 4.

Table 4.1. Specification hydrated poultry litter ash. The table gives the results from weekly analysis of the produced hydrated poultry litter ash of BMC Moerdijk in the period 2013-2014.

Parameter	Unit	Average	Median	Min	Max	Standard deviation	n
Dry matter	% of product	90.4	90.9	81.3	99.9	3.6	58
Loss of ignition ¹	% of dry matter	2.3	1.9	0.1	10.9	1.8	58
Ash	% of dry matter	97.7	98.2	89.1	99.9	1.8	58
Primary nutrients							
P ₂ O ₅	% of product	12.7	12.5	8.5	20.1	2.5	58
K ₂ O	% of product	11.9	11.8	4.2	19.1	2.8	58
Secondary nutrients							
CaO	% of product	25.3	24.6	11.3	38.4	5.3	58
MgO	% of product	5.1	4.9	3.2	7.8	1.0	58
Na ₂ O	% of product	2.0	2.0	0.6	3.0	0.4	58
SO ₃	% of product	5.2	5.3	2.4	7.9	1.0	58
Micronutrients							
B	mg kg ⁻¹ dry matter	159.0	140.0	53.0	570.0	94.0	40
Co	mg kg ⁻¹ dry matter	5.5	<5.0	<5.0	15.0	1.9	58
58Cu	mg kg ⁻¹ dry matter	347.2	340.0	240.0	450.0	53.1	58
Fe	mg kg ⁻¹ dry matter	5,403	4,650	3,400	26,000	3,510	58
Mn	mg kg ⁻¹ dry matter	2,298	2,100	1,300	7,900	1,138	57
Mo	mg kg ⁻¹ dry matter	15.8	16,0	2,4	28,0	5,0	38
Zn	mg kg ⁻¹ dry matter	1,748	1,750	1,200	2,500	324	58
Inorganic contaminants							
As	mg kg ⁻¹ dry matter	<3.0	<3.0	<3.0	5.40	0.35	58
Cd	mg kg ⁻¹ dry matter	0.90	0.84	0.10	1.80	0.33	58
Cr	mg kg ⁻¹ dry matter	16.5	13.0	<10	58.0	10.8	58
Hg	mg kg ⁻¹ dry matter	<0.05	<0.05	<0.05	0.13	0.01	58
Ni	mg kg ⁻¹ dry matter	20.1	18.0	<5.0	62.0	8.3	58
Pb	mg kg ⁻¹ dry matter	8.7	5.4	<5.0	69.0	9.1	58
Other							
Al	mg kg ⁻¹ dry matter	4,359	3,850	2,700	20,000	2,607	58
C	% of dry matter	1.6	1,6	0,5	2,8	0,5	58
Cl	% of dry matter	1.9	1,9	0.0	3.2	0.6	58
F	% of dry matter	<0.01	<0.01	<0.01	<0.01	*	58
H	% of dry matter	0.2	0.2	0.0	0.5	0.1	58
Sb	mg kg ⁻¹ dry matter	<0.1	<0.1	<0.1	2.8	0.2	58
Se	mg kg ⁻¹ dry matter	5.36	5.00	4.46	8.10	0.77	58
Si	mg kg ⁻¹ dry matter	8,473	8,350	520	16,000	3,759	58
Sn	mg kg ⁻¹ dry matter	<0.050	<0.050	<0.050	<0.050	*	58
Te	mg kg ⁻¹ dry matter	<10.0	<10.0	<10.0	<10.0	*	58
Ti	mg kg ⁻¹ dry matter	5.8	5.0	<5.0	12.0	1.7	57
Tl	mg kg ⁻¹ dry matter	0.16	0.15	<0.15	0.9	0.10	57
V	mg kg ⁻¹ dry matter	<1.0	<1.0	<1.0	8.3	3.02	58

 1. Analysed as carbon and present as inorganic carbon (e.g. CaCO₃ and CaCO₃.MgCO₃)

Annex 4.

Table 4.2. Dioxines in hydrated poultry litter ash in the period 2012-2014

Parameter	Unit	Average	Median	Min	Max	Standard deviation	n
2,3,7,8-TCDD	I-TEQ (ng/kg)	<0.74	<0.75	<0.73	<0.76	0.012	14
1,2,3,7,8-PeCDD	I-TEQ (ng/kg)	<0.38	<0.38	<0.074	<0.76	0.184	14
1,2,3,4,7,8-HxCDD	I-TEQ (ng/kg)	<0.070	<0.075	<0.007	<0.076	0.017	14
1,2,3,6,7,8-HxCDD	I-TEQ (ng/kg)	0.082	<0.075	<0.072	0.120	0.015	14
1,2,3,7,8,9-HxCDD	I-TEQ (ng/kg)	<0.076	<0.075	<0.072	0.100	0.007	14
1,2,3,4,6,7,8-HpCDD	I-TEQ (ng/kg)	0.042	0.026	0.012	0.150	0.037	14
OCDD	I-TEQ (ng/kg)	0.008	0.005	0.001	0.036	0.009	14
2,3,7,8-TCDF	I-TEQ (ng/kg)	0.107	0.076	<0.072	0.260	0.057	14
1,2,3,7,8-PeCDF	I-TEQ (ng/kg)	<0.038	<0.037	0.023	0.051	0.007	14
2,3,4,7,8-PeCDF	I-TEQ (ng/kg)	<0.375	0.370	0.038	0.710	0.147	14
1,2,3,4,7,8-HxCDF	I-TEQ (ng/kg)	0.079	<0.076	0.074	0.76	0.027	14
1,2,3,6,7,8-HxCDF	I-TEQ (ng/kg)	0.077	<0.075	<0.007	0.140	0.027	14
2,3,4,6,7,8-HxCDF	I-TEQ (ng/kg)	<0.087	<0.075	<0.007	0.310	0.064	14
1,2,3,7,8,9-HxCDF	I-TEQ (ng/kg)	<0.070	<0.075	<0.007	<0.076	0.017	14
1,2,3,4,6,7,8-HpCDF	I-TEQ (ng/kg)	0.089	0.040	<0.012	0.310	0.094	14
1,2,3,4,7,8,9-HpCDF	I-TEQ (ng/kg)	<0.012	<0.012	<0.012	<0.013	0.000	14
OCDF	I-TEQ (ng/kg)	0.008	0.003	<0.002	0.039	0.010	14
Total	I-TEQ (ng/kg)	1.46	2.00	0	3.30	1.07	14

Annex 5. Organic contaminants in five biochars with (co-digested) animal manure as feedstock.

Parameter	Unit	Biochar made of thick fraction of co-digested pig manure, 300 °C, 30 minutes, 0% O ₂	Biochar made of thick fraction of co-digested pig manure, 300 °C, 45 minutes, 1% O ₂	Biochar made of thick fraction of co-digested pig manure, 400 °C, 30 minutes, 0% O ₂	Biochar made of pelleted solid fraction of digested pig manure, pyrolysis temperature 300 °C	Biochar made of pelleted poultry manure, pyrolysis temperature 300 °C
Moisture content						
Moisture content	%	2.8	2.9	2.7	1.5	0.8
Dioxines						
2,3,7,8-TCDF	ng/kg product	0.67	0.21	0.50	0.08	0.08
1,2,3,7,8-PeCDF	ng/kg product	0.37	0.115	0.27	<0.05	<0.05
2,3,4,7,8-PeCDF	ng/kg product	0.51	0.140	0.43	<0.05	<0.05
1,2,3,4,7,8-HxCDF	ng/kg product	0.19	0.07	0.46	<0.05	<0.05
1,2,3,6,7,8-HxCDF	ng/kg product	0.19	0.070	0.35	<0.05	<0.05
2,3,4,6,7,8-HxCDF	ng/kg product	0.23	0.08	0.43	<0.05	<0.05
1,2,3,7,8,9-HxCDF	ng/kg product	0.05	<0.05	<0.05	<0.05	<0.05
1,2,3,4,6,7,8-HpCDF	ng/kg product	0.30	0.11	1.5	0.12	<0.05
1,2,3,4,7,8,9-HpCDF	ng/kg product	<0.05	<0.05	0.09	<0.05	<0.05
OCDF	ng /kg product	0.11	<0.10	0.3	<0.10	<0.10
Dibenzodioxins						
2,3,7,8-TCDD	ng/kg product	0.16	0.06	0.06	<0.05	<0.05
1,2,3,7,8-PeCDD	ng/kg product	0.63	0.10	0.16	<0.05	<0.05
1,2,3,4,7,8-HxCDD	ng/kg product	0.21	<0.05	0.15	<0.05	<0.05
1,2,3,6,7,8-HxCDD	ng/kg product	0.91	0.161	0.35	<0.05	<0.05
1,2,3,7,8,9-HxCDD	ng/kg product	1.02	0.131	0.18	<0.05	<0.05
1,2,3,4,6,7,8-HpCDD	ng/kg product	2.61	0.65	1.6	0.1	0.1
OCDD	ng/kg product	2.70	0.9	2	0.3	0
WHO-PCDD/F-TEQ						
WHO-PCDD/F-TEQ [lb]	ng TEQ/kg product	1.45	0.31	0.72	0.01	0.01
WHO-PCDD/F-TEQ [ub]	ng TEQ/kg product	1.45	0.32	0.73	0.17	0.17

Parameter	Unit	Biochar made of thick fraction of co-digested pig manure, 300 °C, 30 minutes, 0% O ₂	Biochar made of thick fraction of co-digested pig manure, 300 °C, 45 minutes, 1% O ₂	Biochar made of thick fraction of co-digested pig manure, 400 °C, 30 minutes, 0% O ₂	Biochar made of pelleted solid fraction of digested pig manure, pyrolysis temperature 300 °C	Biochar made of pelleted poultry manure, pyrolysis temperature 300 °C
non-ortho-PCB's						
PCB 81	ng/kg product	0.53	0.29	1.53	0.10	0.12
PCB 77	ng/kg product	4.3	2.7	2	0.3	0.8
PCB 126	ng/kg product	2.04	0.55	0.9	0.07	0.08
PCB 169	ng/kg product	0.58	0.12	0.34	<0.05	<0.05
WHO-NO-PCB-TEQ [lb]	ng TEQ/kg product	0.21	0.06	0.10	0.01	0.01
WHO-NO-PCB-TEQ [ub]	ng TEQ/kg product	0.21	0.06	0.10	0.01	0.01
mono-ortho-PCB's						
PCB 123	ng/kg product	<10	<10	<10	<10	<10
PCB 118	ng/kg product	51	24	19	<10	<10
PCB 114	ng/kg product	<10	<10	<10	<10	<10
PCB 105	ng/kg product	18	<10	<10	<10	<10
PCB 167	ng/kg product	14	<10	<10	<10	<10
PCB 156	ng/kg product	21	<10	<10	<10	<10
PCB 157	ng/kg product	<10	<10	<10	<10	<10
PCB 189	ng/kg product	<10	<10	<10	<10	<10
WHO-MO-PCB-TEQ [lb]	ng TEQ/kg product	0.02	0.00	0.00	0.00	0.00
WHO-MO-PCB-TEQ [ub]	ng TEQ/kg product	0.03	0.02	0.02	0.02	0.02
WHO-PCB-TEQ [lb]	ng TEQ/kg product	0.23	0.06	0.10	0.01	0.01
WHO-PCB-TEQ [ub]	ng TEQ/kg product	0.24	0.08	0.12	0.03	0.03
WHO-PCDD/F-PCB-TEQ [lb]	ng TEQ/kg product	1.68	0.37	0.82	0.02	0.02
WHO-PCDD/F-PCB-TEQ [ub]	ng TEQ/kg product	1.69	0.40	0.85	0.20	0.20

Parameter	Unit	Biochar made of thick fraction of co-digested pig manure, 300 °C, 30 minutes, 0% O ₂	Biochar made of thick fraction of co-digested pig manure, 300 °C, 45 minutes, 1% O ₂	Biochar made of thick fraction of co-digested pig manure, 400 °C, 30 minutes, 0% O ₂	Biochar made of pelleted solid fraction of digested pig manure, pyrolysis temperature 300 °C	Biochar made of pelleted poultry manure, pyrolysis temperature 300 °C
indicator-PCB's						
PCB 028	ng/kg product	<100	<100	<100	<100	<100
PCB 052	ng/kg product	<100	<100	<100	<100	<100
PCB 101	ng/kg product	116	<100	<100	<100	<100
PCB 153	ng/kg product	349	141	<100	<100	<100
PCB 138	ng/kg product	233	100	<100	<100	<100
PCB 180	ng/kg product	340	110	<100	<100	<100
Totaal indicator PCB's [ub]		1238	652	600	600	600
<i>lb met lower bound detectiegrenzen</i>						
<i>ub met upper bound detectiegrenzen</i>						
* Interference						
Organochlorines						
α-HCH	ng/g product	<10	<10	<10	<10	<10
β-HCH	ng/g product	<10	<10	<10	<10	<10
γ-HCH (lindaan)	ng/g product	<10	<10	<10	<10	<10
HCB	ng/g product	<10	<10	<10	<10	<10
Aldrin	ng/g product	<10	<10	<10	<10	<10
Dieldrin	ng/g product	<10	<10	<10	<10	<10
Endrin	ng/g product	<10	<10	<10	<10	<10
Isodrin	ng/g product	<10	<10	<10	<10	<10
o,p'-DDE	ng/g product	<10	<10	<10	<10	<10
p,p'-DDE	ng/g product	<10	<10	<10	<10	<10
o,p'-TDE	ng/g product	<10	<10	<10	<10	<10
p,p'-TDE	ng/g product	<10	<10	<10	<10	<10
o,p'-DDT	ng/g product	<10	<10	<10	<10	<10
p,p'-DDT	ng/g product	<10	<10	<10	<10	<10

Parameter	Unit	Biochar made of thick fraction of co-digested pig manure, 300 °C, 30 minutes, 0% O ₂	Biochar made of thick fraction of co-digested pig manure, 300 °C, 45 minutes, 1% O ₂	Biochar made of thick fraction of co-digested pig manure, 400 °C, 30 minutes, 0% O ₂	Biochar made of pelleted solid fraction of digested pig manure, pyrolysis temperature 300 °C	Biochar made of pelleted poultry manure, pyrolysis temperature 300 °C
PAH						
Naftalene	ng/g product	267	1585	2968	82	55
Phenanthrene/Anthracene **	ng/g product	107	296	1308	148	51
Fluoranthene	ng/g product	<10	63	416	21	19
Benz[a]anthracene	ng/g product	17	50	275	<10	<10
Chrysen	ng/g product	25	97	384	<10	<10
Benzo(b/k)fluoranthene**	ng/g product	42	79	489	<10	<10
Benzo(a)pyrene	ng/g product	46	158	459	11	<10
Indeno[123-cd]pyrene	ng/g product	16	28	110	<10	<10
Benzo[ghi]perylene	ng/g product	17	45	99	<10	<10
** content is sum of two compounds						
Mineral oil (C10-C56)						
Mineral oil (C10-C56)	mg/g product	0.37	0.33	0.31	0.25	0.22