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B-1049 Brussels/Belgium

Freiburg, 04th March 2020

**Position paper in regard to biosolids as feedstock for pyrolysis to be included
in the scope of the Fertilising Products Regulation**

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Dear Ms. Bernsel,

The European Biochar Industry Consortium (EBI) very much appreciates the thorough and elaborate STRUBIAS report established by the JRC. We consider the suggested framework for the inclusion of biochar into the revised EU fertilizer regulation as major step forward towards a safe and sustainable circular economy and agriculture. We would like to seize the opportunity of the final discussion to draw your attention on an important detail in regard to the list of eligible feedstocks for pyrolysis.

The authors of the STRUBIAS report decided to exclude sewage sludge as eligible feedstock for the production of pyrolysis & gasification materials. The precautionary principle advanced by the authors is rather comprehensible given the complexity and degree of contamination of biosolids. However, recent scientific papers not yet considered by JRC demonstrate that at sufficiently severe pyrolysis temperatures (> 500°C) and residence times (> 3 min), all reference organic contaminants and organic micropollutants were completely or nearly completely degraded or driven off the solid material.

To completely exclude even the possibility of including biosolids as pyrolysis feedstock would seal a huge potential of European environmental technology development and disadvantage Europe against the rest of the world in regard to nutrient and carbon recycling of sewage sludge.

We would therefore like to draw your attention to the following key publications that show convincingly the efficiency of pyrolytic degradation of model hormones, antibiotics and other pharmaceuticals. We think that these peer reviewed scientific publications are a convincing base to review the decision and to open the possibility to include biosolids as eligible feedstock for pyrolysis.

The scientific literature in regard to pyrolysis, biosolids and sewage sludge was evaluated through Web of Science (www.webofknowledge.com) in February 2020 using the following key words 2018-2020:

Sewage sludge pyrolysis – 875 hits

Biosolids pyrolysis – 42 hits – 17 additional to the above

Biosolid biochar* – 61 hits – 29 additional to the above

Biosolid pyrolysis* – 50 hits – 2 additional to the above

Sewage sludge biochar – 635 hits – 261 additional to the above

Sewage sludge TGA – 86 hits – 31 additional to the above

This is a total of 1215 publications. Based on title and keywords, 132 publications were identified as relevant and were further evaluated based on their abstract and the full text, which resulted in the following summary:

Studies in regard to organic pollutants

(Hoffman et al., 2016) demonstrates that the pyrolytic treatment of biosolids at a temperature of 400°C almost completely removed (> 95%) estrogenic compounds associated with biosolids. The melting and boiling points of all common estrogens are below 260°C and 440°C, respectively. After the estrogenic compounds melt into the liquid phase they will partition to the gas phase (away from the biochar) as the liquid-gas phase equilibrium is approached. These compounds will thus presumably have volatilized at pyrolysis temperatures of 500°C. After initial volatilization from the biochar, the estrogenic compounds could either partition to the pyrolysis oil or pyrolysis gas, or be transformed through thermal decomposition. The authors conclude: “*pyrolysis of biosolids can be used to produce a valuable soil amendment product, biochar, that minimizes discharge of estrogens to the environment.*”

(Ross et al., 2016) demonstrate that pyrolytic treatment at 500°C removed after less than 5 minutes more than 90% of microconstituents like the antibiotic triclocarban, the pharmaceutical conservation agent triclosan as well as the non-ionic tenside nonylphenol (to be found in pharmaceuticals, fungicides, paints etc.) from the solid residue. At 600°C nonylphenol was even below the detection limit.

Their fate studies revealed that microconstituents were both volatilized and thermochemically transformed during pyrolysis. Reductive dehalogenation products of triclocarban and suspected dehalogenation products of triclosan were identified in pyrolysis gas and would be completely degraded by the usual pyrogas combustion. The authors conclude: “**Application of biosolids-derived biochar to soil in place of biosolids has potential to minimize**

organic microconstituents discharged to the environment provided appropriate management of pyrolysis gas and pyrolysis oil (the latter is usually co-combusted in sewage pyrolysis).

(Ross et al., 2016) was referenced by the STRUBIAS report but unfortunately to express the contrary of the paper's main message, i.e. "*the limitations of the potential of dry and wet pyrolysis/gasification processes to remove organic pollutants*" at lower temperatures than 500°C).

A study published by the German Ministry of Environment in 2019 (**Bundesumweltamt 2019**) investigated pharmaceutical residues of various biosolids after pyrolytical treatments above 500 °C. The selected substances were Ciprofloxacin, Levofloxacin, Clarithromycin, Carbamazepin, 17- α -Ethinylestradiol, Diclofenac, Cefuroxim, Sulfamethoxazol, 17- β -Estradiol, Metoprolol and Bezafibrate. Following the pyrolysis treatment with operating temperatures above 500 °C all values of the investigated pharmaceuticals were below the detection limit. The authors concluded: With thermo-chemical treatments (i.e. pyrolysis) **a complete destruction of the pharmaceutical residues is achieved**. No further technical treatment measures are necessary.

(**Zielińska & Oleszczuk, 2015**) found that the conversion of biosolids to biochar reduced total PAH content from 8 to 25-fold compared to the original biosolids.

(**Biswal & Singh, 2004**) performed thermogravimetric analyses (TGA) of flocculants that are potentially used in wastewater treatment. These substances were effectively destroyed at 400 °C.

(**Dai et al., 2018**) evaluated the **fate of PCDD/Fs during sewage sludge pyrolysis**. PCDD/Fs were partially dechlorinated during pyrolysis, but the main factor determining their fate was distillation. Comparing sewage sludge char with the untreated sewage sludge, 98-99% of PCDD/Fs and about 90% of PCDD/Fs toxicity quantified in I-TEQ (International Toxicity Equivalent Quantity) were eliminated under relevant pyrolysis conditions (500-700 °C).

(**Kimbell et al., 2018**) showed that a pyrolysis of 5 minutes at 500 °C is sufficient to eliminate **all genes including antibiotic resistance genes below the detection limit**.

Pyrolysis reduces availability of polyaromatic hydrocarbons (PAHs): (**Fristak et al., 2018**) showed that pyrolysis **can eliminate 90% of the total content of 16 EPA-PAH** of sewage sludge which is similar to the findings of other studies, e.g. Kong et al., 2019 and the review of Liu et al., 2018.

(**Simon et al., 2018**) performed **toxicity tests with enchytraeids** and found that **no harmful effects would be expected at application rates of sewage sludge char of $\leq 11.5 \text{ t ha}^{-1}$** . We expect that in praxis, application rates would not exceed 1-3 t ha⁻¹.

A review paper on “*Biochar from biosolids pyrolysis*” was published by (**Paz-Ferreiro et al., 2018**). The paper convincingly shows the potential of various pyrolyzed biosolids to increase crop yield, enhance soil enzymatic activity, increase microbial biomass in soil, improve compost quality, reduce GHG emissions, reduce NH₄ and NO₃ leaching and to preserve most of the initial P (> 90%) in a plant available form. The authors conclude: “*Pyrolysis of biosolids leads to several benefits, compared to the traditional landfilling, incineration or land application. This includes few gaseous emissions, the destruction of pathogens, the potential to recover energy and a solid product, which can be used as a soil amendment. The nutrient content of biochars prepared from biosolids is high, in particular for phosphorus. Paradoxically, very limited work exists concerning the use of biosolids biochar as a product to improve agronomic performance. This could be due to **concerns of toxicity via the food chain, which seems irrational given the demonstrated ability of biochar to immobilize pollutants, in particular heavy metals. The use of biochar for growing non-edible plants in horticulture, as a substitute for other growing media materials, could mitigate these concerns.***”

Another exhaustive review paper about the **characteristics and applications of biochars derived from wastewater solids** was published by (**Liu et al., 2018**). The authors propose an integrated wastewater treatment process that produces and uses wastewater biochar for a variety of food, energy, and water (FEW) applications. The review paper provides a valuable overview about the general topic and confirm that all relevant organic pollutants are eliminated or reduced to an extent that the resulting materials can be applied without damaging the environment, the food chain or users.

A multitude of further studies demonstrated **agronomic benefits** of applying biochar made from biosolids, the following are a short selection of most relevant publications:

(**de Figueiredo et al., 2019**) found that sewage sludge chars produced at 300 and 500 °C increased the colonization of maize roots with arbuscular mycorrhiza fungi (AMF) and therefore **improve mutualistic symbiotic association of maize and AMF**.

(**Mierzwa-Hersztek et al., 2018**) found that sewage sludge char **increased the biomass production** in *Poa pratensis* by up to 100% compared to a non-amended control under lab conditions.

(**Gonzaga et al., 2019**) found **significantly increased biomass production** of Indian mustard over three years after sewage sludge char amendment to tropical soil.

(**Grutzmacher et al., 2018**) found that amendment with sewage sludge char **reduced fertilizer induced N₂O emissions by 87%** in a microcosm experiment.

Many studies are published in regard to heavy metals originated from the biosolid feedstock. We do not summarize those here as the thresholds for heavy metals suggested by the STRUBIAS report would already assure that no heavy metal contamination could occur.

Summary

Thanks to the scientific literature published since 2016 and especially during the last two years, a new risk assessment of the agricultural application of pyrolyzed biosolids became possible. We therefore would like to suggest to reconsider the inclusion of biosolids as eligible feedstock for pyrolysis & gasification materials (biochars).

Since all of the cited scientific studies including the one from the German Ministry of Environment have shown that organic pollutants from the sewage are efficiently destroyed in all investigated pyrolytic treatment processes with temperatures above 500 °C and residence times above 3 min, it can be concluded that the application of pyrolyzed biosolids to agricultural soils should not be excluded by the new EU fertilizer regulations.

Best regards,



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Helmut Gerber
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Cited literature

- Agrafioti E, Bouras G, Kalderis D, Diamadopoulos E (2013) Biochar production by sewage sludge pyrolysis. *Journal of Analytical and Applied Pyrolysis*, **101**, 72–78.
- Biswal DR, Singh RP (2004) Characterisation of carboxymethyl cellulose and polyacrylamide graft copolymer. *Carbohydrate Polymers*, **57**, 379–387.
- Bundesumweltamt (2019) Arzneimittelrückstände in Rezyklaten der Phosphorrückgewinnung aus Klärschlämmen, Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit, Forschungskennzahl 3715 33 401 0, UBA-FB 002724
(https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-03-29_texte_31-2019_arzneimittelrueckstaende-klaerschlamm_v2.pdf)
- EBC (2012) European Biochar Certificate - Guidelines for a Sustainable Production of Biochar. Version 7.1 of 22th December 2015. *European Biochar Foundation*, Version 7.1 of 22th December 2015.
- Dai, Q. J., J. M. Wen, X. G. Jiang, L. Y. Dai, Y. Q. Jin, F. Wang, Y. Chi and J. H. Yan (2018). "Distribution of PCDD/Fs over the three product phases in wet sewage sludge pyrolysis." *Journal of Analytical and Applied Pyrolysis* **133**: 169-175.
- de Figueiredo, C. C., J. K. M. Chagas, J. da Silva and J. Paz-Ferreiro (2019a). "Short-term effects of a sewage sludge biochar amendment on total and available heavy metal content of a tropical soil." *Geoderma* **344**: 31-39.
- de Figueiredo, C. C., W. M. Farias, T. R. Coser, A. M. de Paula, M. R. S. da Silva and J. Paz-Ferreiro (2019b). "Sewage sludge biochar alters root colonization of mycorrhizal fungi in a soil cultivated with corn." *European Journal of Soil Biology* **93**: 6.
- Fristak, V., M. Pipiska and G. Soja (2018). "Pyrolysis treatment of sewage sludge: A promising way to produce phosphorus fertilizer." *Journal of Cleaner Production* **172**: 1772-1778.
- Gonzaga, M. I. S., D. C. F. de Souza, A. Q. de Almeida, C. Mackowiak, I. D. Lima, J. C. D. Santos and R. S. de Andrade (2019). "Nitrogen and phosphorus uptake efficiency in Indian mustard cultivated during three growth cycles in a copper contaminated soil treated with biochar." *Ciencia Rural* **49**(1): 8.
- Grutzmacher, P., A. P. Puga, M. P. S. Bibar, A. R. Coscione, A. P. Packer and C. A. de Andrade (2018). "Carbon stability and mitigation of fertilizer induced N₂O emissions in soil amended with biochar." *Science of the Total Environment* **625**: 1459-1466.
- Hagemann N, Spokas K, Schmidt H-P, Kägi R, Böhler MA, Bucheli TD (2018) Activated carbon, biochar and charcoal: Linkages and synergies across pyrogenic carbon's ABCs. *Water (Switzerland)*, **10**.

- Haider G, Steffens D, Müller D, Kammann C. (2016) Standard Extraction Methods may underestimate Nitrate Stocks captured by Field-Aged Biochar. *Journal of Environment Quality*, **45**.
- Hoffman TC, Zitomer DH, McNamara PJ (2016) Pyrolysis of wastewater biosolids significantly reduces estrogenicity. *Journal of Hazardous Materials*, **317**, 579–584.
- Jin J, Li Y, Zhang J et al. (2016) Influence of pyrolysis temperature on properties and environmental safety of heavy metals in biochars derived from municipal sewage sludge. *Journal of Hazardous Materials*, **320**, 417–426.
- Kammann CI, Schmidt HP, Messerschmidt N et al. (2015) Plant growth improvement mediated by nitrate capture in co-composted biochar. *Scientific reports*, 11080.
- Kimbell, L. K., A. D. Kappell and P. J. McNamara (2018). "Effect of pyrolysis on the removal of antibiotic resistance genes and class I integrons from municipal wastewater biosolids." *Environmental Science-Water Research & Technology* **4**(11): 1807-1818.
- Kong, L. L., J. Z. Liu, Q. Han, Q. X. Zhou and J. H. He (2019). "Integrating metabolomics and physiological analysis to investigate the toxicological mechanisms of sewage sludge-derived biochars to wheat." *Ecotoxicology and Environmental Safety* **185**: 9.
- Liu, Z. Z., S. Singer, Y. R. Tong, L. Kimbell, E. Anderson, M. Hughes, D. Zitomer and P. McNamara (2018). "Characteristics and applications of biochars derived from wastewater solids." *Renewable & Sustainable Energy Reviews* **90**: 650-664.
- Mierzwa-Hersztek, M., K. Gondek, A. Klimkowicz-Pawlas, A. Baran and T. Bajda (2018). "Sewage Sludge Biochars Management-Ecotoxicity, Mobility of Heavy Metals, and Soil Microbial Biomass." *Environmental Toxicology and Chemistry* **37**(4): 1197-1207.
- Paz-Ferreiro J, Nieto A, Méndez A, Askeland M, Gascó G (2018) Biochar from Biosolids Pyrolysis: A Review. *International Journal of Environmental Research and Public Health*, **15**, 956.
- Ross JJ, Zitomer DH, Miller TR, Weirich CA, McNamara PJ (2016) Emerging investigators series: Pyrolysis removes common microconstituents triclocarban, triclosan, and nonylphenol from biosolids. *Environmental Science: Water Research and Technology*, **2**, 282–289.
- Simon, M., I. Garcia, M. Diez-Ortiz and V. Gonzalez (2018). "Biochar from Different Carbonaceous Waste Materials: Ecotoxicity and Effectiveness in the Sorption of Metal(loid)s." *Water Air and Soil Pollution* **229**(7): 12.
- Zielińska A, Oleszczuk P (2015) Evaluation of sewage sludge and slow pyrolyzed sewage sludge-derived biochar for adsorption of phenanthrene and pyrene. *Bioresource Technology*, **192**, 618–626.