

A photograph of an industrial facility, likely a wastewater treatment plant, featuring large stainless steel tanks, pipes, and blue KSB pumps. Labels on the equipment include "Digestat Liquide Concentré" and "Evaporation".

# Suggested standards for fertilisers to sustainably recycle nutrients

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Front page photo: Details of manure processing plant, Cooperl Environment in Lamballe, Bretagne.

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## Preface

The present report has been prepared in connection to the Interreg Baltic co-funded project, CiNURGi, as a contribution to Task A1.2: "Draft industry standards for evaluation and quality assurance of recycled nutrient fertilizers".

The CiNURGi project aims at supporting the development towards a circular economy for nutrients in the Baltic Sea Region. The initiative focuses on upgrading current infrastructure and technology to enhance nutrient recycling from organic wastes from agricultural, municipal, and industrial sources. CiNURGi is led by RISE Research Institutes of Sweden, supported by a consortium of 24 partners and 13 associated organizations from various countries around the Baltic Sea.

The report identifies the need for a clear definition of fertilisers intended for nutrient recycling, specifically one that separates them from soil improvers. It states that creating comprehensive standards that apply equally to both fertilisers used for nutrient recycling and soil improvers is not practical. Accordingly, it puts forward key standards for bio-based fertilisers.

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Organe Institute

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## Summary in English

Enhanced nutrient recycling from agricultural, municipal, and industrial wastes is essential for achieving the objectives of the EU's Farm-to-Fork strategy, which seeks to reduce fertiliser use by at least 20% and nutrient losses by 50% by 2030. This approach is equally pertinent to the Baltic Sea Region, where the Helsinki Commission (HELCOM) has established targets for a further 10% reduction in nitrogen (N) inputs and a 20% reduction in phosphorus (P) inputs, aiming to achieve a "Baltic Sea unaffected by eutrophication." A primary means of lowering fertiliser consumption and mitigating N and P losses to the environment is through the advancement of nutrient recycling practices within organic wastes originating from agricultural, industrial, and municipal sources.

The Interreg Baltic cofinanced CiNURGi project contributes to these objectives by promoting the increased production of bio-based fertilisers (BBFs). Part of the issue is that nutrients in organic waste, particularly phosphorus, are present in excess in some regions. As a result, converting these nutrients into more concentrated forms can make interregional transport more cost-effective.

To advance the market for bio-based fertilisers (BBFs), and to earn the confidence of crop farmers as well as their willingness to invest in these products, CiNURGi aims to establish standards for BBF trade. Creating effective standards requires clear definitions of their intended scope. Differing interpretations of fertilisers and soil improvers can hinder the establishment of robust standards for bio-based fertilisers. Accordingly, this technical report provides definitions for these and other relevant terms, forming the foundation for proposed standards.

Based on Foged et al. (2025b), nine key aspects for valuation of BBF's, and therefore for the development and function of a market for BBF's are established: 1) high nutrient concentration (N and/or P), 2) declared and documented quality, 3) stable quality, 4) permission for use in certified organic farming, 5) organic matter content, 6) nutrient availability, 7) content of unwanted substances, 8) ease of handling and 9) social economy.

Relevant standardisation issues are grouped and suggested as follows: 1) Bio-based fertilisers as well as nutrient rich wastes distinguish from soil improvers and nutrient poor waste by having more plant available N + P<sub>2</sub>O<sub>5</sub> than the content of Effective Organic Matter divided by 20. 2) Apart from compulsory declaration/labelling according to EU's Fertilising Products Regulation, is recommended that buyers of BBF's are provided the following additional information: i) Whether the BBF is approved for certified organic farming in accordance with Annex II of Commission Implementing Regulation (EU) 2021/1165. ii) Assumed Humification Coefficient with reference to scientific evidence for bio-based fertilisers produced with similar processing technology. iii) N and P nutrient availability, in general the amount of mineralised N and the amount of water extractable P, with reference to analyses and field trials carried out by impartial organisations. iv) A short guidance about requirements to transporting and storage, which is much related to the physical form of the BBF,

and in addition guidance on field-spreading of the BBF, such as suitable spreading equipment. The additional information can be based on voluntary agreements with the BBF suppliers or their branch organisation, alternatively be requested via national legislation. 3) Realising wide differences in current regulated limit values for pollutants, a paradigm shift is proposed, namely that permittance to spread organic wastes and BBF's on soils shall be conditioned that the soils are not already deemed unhealthy by the EU Soil Observatory (EUSO) due to content of a pollutant in question or a low biodiversity, and that it is the amount of the specific pollutant that decides whether field spreading can happen without risk for compromising soil health, not the concentration of the pollutant in the field-spread material. In this way, the regulation of soil pollution would be based on the same principles as is the case for water and air. It is recommended that concrete figures for Allowed Field Spreading (AFS's) amounts per ha per year are defined for relevant pollutants, taking into consideration the time it takes for the given pollutant to be degraded in or migrated from the soils. 4) Is it recommended to prohibit the production of soil improvers from nutrient rich wastes, since this leads to unacceptable losses of N and P as well as carbon and organic matter at the cost of the environment and climate. A general principle shall be that the capitalised social economic value of environmental and climate impacts of BBF production must be positive.

## Dansk sammenfatning

Øget recirkulering af næringsstoffer i landbrugs-, kommunalt og industrielt affald er relevant og nødvendigt for at nå EU's "jord-til-bord"-strategi, der sigter mod en reduktion af gødningsforbruget på mindst 20 % inden 2030 samtidig med en reduktion af næringsstofftab på 50 %. Dette gælder ikke mindst for Østersøregionen, hvor Helsinki-kommissionen (HELCOM) har sat mål om yderligere 10 og 20 % reduktion af kvælstof (N) og fosfor (P) tilførslen for at opnå en "Østersø upåvirket af eutrofiering". En vigtig nøgle til at reducere gødningsforbruget og N+P-tabet til miljøet er en øget recirkulering af næringsstoffer i organisk affald fra landbrug, industri og kommuner.

Det Interreg Baltic-medfinansierede CiNURGi-projekt støtter disse mål, blandt andet ved at fremme en øget produktion af biobaseret gødning (BBG), da en del af problemkomplekset er, at næringsstoffer i organisk affald, især P, er i overskud i nogle regioner og derfor bør omdannes til mere koncentrerede former, der gør interregional transport mere omkostningseffektiv.

For at støtte udviklingen af markedet for BBG'er, ikke mindst for at opnå tillid hos planteavlere til sådanne gødninger, og deres villighed til at betale for dem, har CiNURGi ambition om at udvikle standarder for handel med BBG'er. En grundlæggende forudsætning for udvikling af standarder er, at det er defineret, hvad disse skal gælde for. Forskellige opfattelser af betydningen af gødning og jordforbedringsmidler ville hindre muligheden for at definere meningsfulde standarder for biobaserede gødninger, og definitionen af disse og andre relevante termer er derfor foretaget i denne tekniske rapport som grundlag for foreslåede standarder.

Baseret på Foged et al. (2025b) er ni nøgleaspekter for værdiansættelse af BBG'er, og dermed for udviklingen og funktionen af et marked for BBG'er, etableret: 1) høj næringsstofkoncentration (N og/eller P), 2) deklareret og dokumenteret kvalitet, 3) stabil kvalitet, 4) tilladelse til brug i certificeret økologisk landbrug, 5) indhold af organisk materiale, 6) tilgængelighed af næringsstoffer, 7) indhold af uønskede stoffer, 8) nem håndtering og 9) socialøkonomi. Relevante standardiseringsaspekter er grupperet og foreslået som følger: 1) Biobaserede gødningsstoffer samt næringsrige affaldsstoffer adskiller sig fra jordforbedringsmidler og næringsfattigt affald ved at have mere plantetilgængeligt N + P<sub>2</sub>O<sub>5</sub> end indholdet af effektivt organisk materiale divideret med 20. 2) Udover obligatorisk deklaration/mærkning i henhold til EU's gødningsproduktforordning anbefales det, at købere af BBG'er får følgende yderligere oplysninger: i) Om BBG'en er godkendt til certificeret økologisk landbrug i overensstemmelse med bilag II til Kommissionens gennemførelsesforordning (EU) 2021/1165. ii) Antaget Humificerings Koefficient med henvisning til videnskabelig evidens for biobaserede gødningsstoffer produceret med lignende forarbejdningsteknologi. iii) Tilgængelighed af N- og P-næringsstoffer, generelt mængden af mineraliseret N og mængden af vandekstraherbart P, med henvisning til analyser og markforsøg udført af upartiske organisationer. iv) En kort vejledning om krav til transport og opbevaring, som er meget relateret til BBG'ens fysiske form, og derudover vejledning om markspredning af BBG, såsom passende spredeudstyr. De yderligere oplysninger kan

kræves via frivillige aftaler med BBG-leverandørerne eller deres brancheorganisation, alternativt via national lovgivning. 3) I betragtning af de store forskelle i de nuværende regulerede grænseværdier for forurenende stoffer foreslås et paradigmeskift, nemlig at tilladelse til markspredning af organisk affald og BBG skal være betinget af, at jorderne ikke allerede er vurderet som usunde af EU's Jordbundsobservatorium (EUSO) på grund af indholdet af et bestemt forurenende stof eller lav biodiversitet, og at det er mængden af det specifikke forurenende stof, der afgør, om markspredning kan ske uden risiko for at kompromittere jordens sundhed, ikke koncentrationen af forurenende stoffet i det markspredte materiale. På denne måde vil reguleringen af jordforurening være baseret på de samme principper som for vand og luft. Det anbefales, at der defineres konkrete tal for tilladt markspredning (AFS) pr. ha pr. år for relevante forurenende stoffer under hensyntagen til den tid, det tager for det givne forurenende stof at blive nedbrudt i eller migreret fra jorderne. 4) Det anbefales at forbyde produktion af jordforbedringsmidler fra næringsrigt affald, da dette fører til uacceptable tab af N og P samt kulstof og organisk materiale på bekostning af miljøet og klimaet. Et generelt princip skal være, at den kapitaliserede samfundsøkonomiske værdi af miljø- og klimapåvirkninger fra en given BBF-produktion skal være positiv.

## 1: Background

Increased recycling of nutrients in farming, municipal and industrial wastes is relevant and necessary for reach of EU's Farm-to-Fork strategy<sup>1</sup>, aiming for at least a 20% reduction in fertiliser use by 2030 alongside a 50% reduction in nutrient losses.

This is not least the case for the Baltic Sea Region, since the Baltic Sea is eutrophicated and the Helsinki Commission (HELCOM) has set goals for a further reduction of its load with plant nutrients, nitrogen (N) and phosphorus (P). HELCOM's overarching goal for nutrient reduction in the Baltic Sea is to achieve a "Baltic Sea unaffected by eutrophication," which means minimising nutrient inputs from human activities to ensure good environmental status and ecological balance. This is achieved through the HELCOM "Nutrient input reduction scheme", which sets Maximum Allowable Inputs (MAI) for nitrogen and phosphorus into sub-basins and Nutrient Input Ceilings (NIC) for each country to reach these targets. For 2022, HELCOM has concluded<sup>2</sup> that the N and P loads to the Baltic Sea is 10 and 20% above the defined MAI, especially caused by excessive N and P inputs in the Gulf of Finland and the Baltic Proper, and less the Gulf of Riga, whereas nutrient inputs to other sub-basins of the Baltic Sea did not exceed their defined MAI's.

Nutrient recycling is closely connected with policies as well as projects and other measures to support their implementation. Having defined terms related with nutrient recycling provides clarity and avoids misunderstandings, not least about the scope, when dealing with related measures, policies, research, investments and other.

This technical report is made as a contribution to Task 1.2 of the CiNURGi project<sup>3</sup>. CiNURGi aims at an increased recycling of nutrients in wastes from agriculture, industry and municipals. Task 1.2 has the objective to draft standards for fertilisers that contain recycled nutrients.

In the following section 2 provides suggested definition of related terms, and thereby the scope for standards to define. Thereafter, section 3 outlines key aspects for valuation of fertilisers containing recycled nutrients, and section 4 suggested key standards for these.

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<sup>1</sup> [https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy\\_en](https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en)

<sup>2</sup> <https://indicators.helcom.fi/indicator/inputs-of-nutrients/>

<sup>3</sup> <https://interreg-baltic.eu/project/cinurgi/>

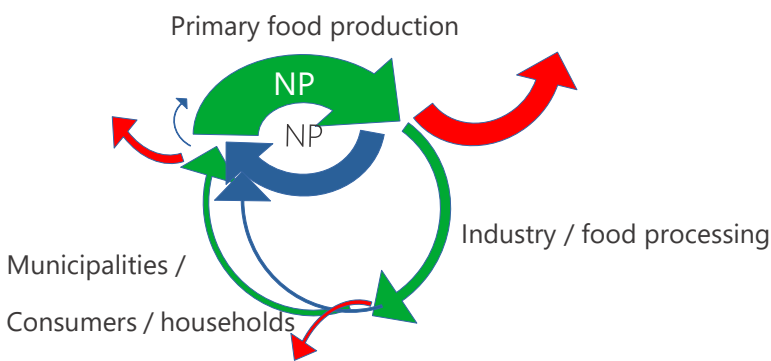
## 2: Suggested definition of related terms

It is impossible to determine meaningful standards unless the item in question has been defined. For instance, it would not give much meaning to define standards comprising motor bikes and cars, although they both are vehicles. Within the CiNURGi project and in general, there is especially diverging perceptions about fertilisers and soil improvers, the CiNURGi term “Nutrient Recycling Fertilisers” causes confusion since it is not defined by the project or elsewhere, and there also appear to be some confusion about the meaning of recycling. In the follow, we do therefor provide suggested definitions to delineate the scope for later suggested standards.

### 2.1: Primary food production is the pivotal point of N and P recycling

Recycling of nutrients happen when these are used for fertilising. Veeken et al. (2017) writes in line with this that “Nutrient recycling mainly involves the recycling of organic waste or residual sources from agricultural, industrial and communal activities.” and “Nutrient recycling is mainly focused on nitrogen (N) and phosphate (P) as these components can replace chemical fertilisers to minimise extraction of fossil P resources and to reduce the environmental impacts of mineral nitrogen fertiliser production.”

Figure 1 illustrates the scope of nutrient recycling as well as the direct and the indirect part as well as losses.



*Figure 1: The scope of N and P nutrient recycling comprise primary food production, food processing industries and households. The width of the green arrows symbolises the N and P nutrients that are currently recycled in the food chain, the blue ones the part that is recycled as nutrients in raw or processed wastes, and the red ones the N and P that currently is lost, representing the potential for increased nutrient recycling.*

As Figure 1 illustrates, nutrient recycling takes it basis in primary food production, the plant and animal production, and it means that N and P both stems from and is led back to the primary food production. Nutrient recycling can be increased via both higher cycling in the food chain, and via nutrients in raw or processed wastes that is used for fertilisation. The recycling as wastes (blue arrow) is high in farming but could be improved substantially if nutrient losses (red arrow) were

reduced. The cycling from farming to food processing is small, for instance only about 10% in the case of P (Rothwell, 2020).

Recommended standards for the largest blue arrow in Figure 1, namely the recycled nutrients in livestock manures, are already defined in HELCOM Recommendation 41/3 (2020), based on a policy brief of BalticCOMPASS (Foged, 2011).

Potassium (K), which is the third most important plant nutrient evaluated from crop demands, has a negligible role when speaking about nutrient recycling, since its potential harm of the environment is minimal, the content of K in wastes are typically not even analysed/known, since it most often is considered a passive part of many bio-based fertilisers, and crops' K demand typically met when fertilising with bio-based fertilisers up to crops demands for N and P.

## 1.2: Distinguishing fertilisers from soil improvers

Veeken et al (2017) writes that "Fertilisers are a source of readily available nutrients and have a direct, short-term effect on plant growth. Soil improvers affect plant growth indirectly by improving the physical and biological properties of the soil, such as water retention, aeration and microbial activity and diversity." Any meaningful defining of standards for two materials with so different functions must therefore be considered separately.

On this background, Veeken et al. (2017) has suggested a to distinguish between fertilisers and soil improvers, recognising the need for that, also referring to EU's Fertilising Products Regulation (FPR) (European Commission, 2019)<sup>4</sup>, which fails to provide such a definition. Analysing 28 organic waste types of agricultural, industrial and municipal origin in Netherlands, Flandern, Germany and Denmark, leads to the conclusion that organic soil improvers have EOM/N-mineral > 150 and EOM / P<sub>2</sub>O<sub>5</sub> > 35 on a kg/kg basis, where EOM stands for Effective Organic Matter, found by multiplying the organic matter content with a Humification Coefficient (HC) factor. Examples of HC is 0.33 for pig manure, 0.7 for cattle manure and 0.9 for compost.

The proposed definition of Veeken et al. (2017) means that materials like manures, digestates and slurry generally falls into the category of fertilisers while composts generally fall into the category of soil improvers, being in line with general perceptions. However, the suggested definition has some inherent inadequacies:

- It seems correct that the definition is based on mineralised N, since organic bound N is not readily available for the crop but provides a long-term effect on the soil fertility. However,

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<sup>4</sup> <https://eur-lex.europa.eu/eli/reg/2019/1009/oj/eng>

the similar should be the case for P, since a large share of P in organic wastes and bio-based fertilisers typically is organic bound and not readily available for the crop.

- It is inadequate that the definition includes a “and”, wherefore a condition must be fulfilled for both N and P. This means for instance that a material like bio-waste compost is defined as a fertiliser, since its EOM/P<sub>2</sub>O<sub>5</sub> is 34, while the EOM/N-mineral is 373. Also, the current definition would exclude bio-based fertiliser that contain alone P or N, for instance ammonia sulphate solution. It seems more relevant with a definition based on one criterium that includes both plant available N and P.

CiNURGi mention in the project description summary that “increasing circularity of nutrients is essential to decrease nutrient losses and also reduce our dependency and use of imported mineral nutrients”. There is thus no doubt the project is related to fertilisers, and not to soil improvers, which are not mentioned in the project description.

### 1.3: Unclear meaning of nutrient-rich wastes

In the literature, the term nutrient-rich waste is often used, but without giving any definition of it. Nutrient-rich wastes are claimed to cause environmental damage if dumped in the environment, see for instance Vaneekhaute (2021). Nutrient-rich waste can be used for production of bio-based fertilisers, for instance mentioned by Kurniawati (2023), calling the wastes for by-streams.

The term nutrient-rich is used for wastes like pig slurries, which apparently is in contradiction to a low N + P content of about 0.6%<sup>5</sup>, and similar for other waste types. In comparison, the N + P nutrient content in many other materials, for instance 1.7% in wheat flour and 46% in urea.

In contrary to nutrient-rich, the term nutrient-poor is not commonly used in the literature. One example of using the term nutrient-poor is given by Castán et al. (2016), who use the term for solid fractions of municipal solid wastes. However, the confusion being that Castán et al. (2016) does not provide any definition and that the term nutrient-rich is used in the same article for manure composts, which typically has a low N + P content of 2.2% of DM<sup>6</sup>, but on basis of an almost 10-fold higher DM content than pig slurry and farmers do not consider compost as a fertiliser, not a component you see in a fertiliser plan, since the level of plant available N and P is minimal. Compost is primarily used as a soil improver, to improve the organic matter content of the soil to benefit microbial activity and water binding capacity and the fertilising effect considered a secondary and minor, long-term effect. On a dry matter basis, the content of N + P in pig slurry is 10.5%, but only

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<sup>5</sup> Average of pig slurry examples in <https://www.agrotechnologyatlas.eu>

<sup>6</sup> Average of manure compost examples in <https://www.agrotechnologyatlas.eu>

4.5 % in manure compost, using the abovementioned examples from AgroTechnologyATLAS. Compared to pig slurry, it would therefore be fair to call manure compost for nutrient-poor.

Thus, the term nutrient-rich appear to be used freely at the authors' discretion, where it associates with the used argumentation and supports envisaged conclusions, which is not constructive or rational for reach of joint understanding for ways to optimise nutrient recycling.

So-called nutrient-rich wastes are used for production of soil improvers at a great cost for the environment. For instance, Tiquia et al. (2002) found that composting of pig manure meant a loss of 30-63% of carbon (C) in the form of carbon dioxide and methane greenhouse gases, a loss of nitrogen (N) of 37-60% via leaching and runoff and emissions of ammonia and laughing gas, and losses of phosphorus (P) of 23-39% via runoff and leaching. Similarly, Elsgaard et al. (2022) reports that the availability of N in biochar is generally low, and furthermore that there are even found a decline in soil mineral N after application of biochar. In line with that, the Danish fertilisation regulations (Landbrugsstyrelsen, 2022) do not require any N effect of biochar application, meaning they consider the N availability of biochar to be zero. Similarly, Elsgaard et al. (2022) reports that the availability of P is lower than in the feedstock applied directly to soil during the first days after application to soil, but cause the soil P availability to increase over time, but it is not clear, whether the P stems from the biochar or the soil pool, and therefore not whether the long term effect of higher soil P availability shall be attributed to biochar, or rather is an indirect effect of the addition of biochar to the soil.

## 1.4: Bio-based fertilisers is an acknowledged term

Where it is not feasible to use the organic wastes in raw form for fertilising, the nutrient recycling requires processing into fertiliser products.

The recent amended Fertilising Products Regulation (FPR) (European Commission, 2019) defines 7 Product Function Categories (PFC's) (with several sub-categories) and 11 Component Material Categories (CMC's). However, these PFC's and CMC's do not consider the origin of the material, such as whether it is a recycled product. Despite the FPR deals with both organic soil improvers and organic fertilisers, no clear definition to distinguish these are provided. Despite the FPR in its preamble mentions recycling, it does not specify any relation of this with the defined PFC's and CMC's. The FPR is therefore not instrumental in relation to the reach of the abovementioned Farm-to-Fork and other policy goals.

The LEX4BIO<sup>7</sup> project has among other contributed to make the Bio-Based Fertiliser (BBF) term generally recognised for characterising fertilisers containing nutrients from wastes of agricultural, industrial or municipal sources. The European Sustainable Phosphorus Platform (ESPP) has taken the initiative to formulate a definition of BBF's, and so far, a draft position paper is developed<sup>8</sup>.

The processing of wastes into BBF's can be of mechanical (physical), biological, thermal or chemical nature, or a combination of these. Chemicals are added in the production of BBF's in many cases, for instance in the form of sulphuric acid. The draft ESPP definition of BBF's outlines the possibility for setting a limit for added mineral/chemical plant nutrients in the final BBF product and the possibility for denominating a product for a partly bio-based fertiliser in such cases.

## 1.5: Aim of this technical report

Given the scope outlined by the definition of recycling and bio-based fertilisers, the following sections lists aspects of importance for the valuation of fertilisers containing recycled N and P nutrients, seen from crop farmers and the society's perspective, and it outlines standards in the case of these key aspects.

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<sup>7</sup> <https://lex4bio.eu/>

<sup>8</sup> [https://www.phosphorusplatform.eu/images/Regulatory%20activities/ESPP%20proposals%20Bio-Based%20Fertilisers%20v8\\_1\\_24.pdf](https://www.phosphorusplatform.eu/images/Regulatory%20activities/ESPP%20proposals%20Bio-Based%20Fertilisers%20v8_1_24.pdf)

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## 2: Key aspects for valuation of bio-based fertilisers

Farmers willingness to pay for BBF's is generally low, and according to Moshkin et al. (2023) 30-46% lower than for nutrients in mineral fertilisers. Foged et al. (2025b) has via interviews and discussions with farmers got an insight into the reasons for that, which has given inspiration for the following list of key aspects for valuation of BBF's:

- Nutrient concentration, declaration and stability

BBF's do often have a higher N and P nutrient concentration than the influent organic wastes, reducing transportation and other handling costs.

Higher nutrient concentration can be due to a processing method that extracts/recover nutrients from the organic wastes, such as in the case of scrubbing.

Farmers appreciate a high N and P nutrient concentration in BBF's, especially for the N content. The higher the BBF nutrient concentration is, the smaller is the dose that meets the nutrient demand of the crop. Smaller doses mean in general smaller storage requirements, lower spreading costs, and lower risk for soil compaction during spreading.

It is in this connection a clear wish of farmers to have the BBF nutrient concentration declared. It is also seen as an advantage if the quality is similar from one delivery to another, which makes it easier for the farmer to understand how it can be incorporated into the fertilisation of different crops.

- Labelled as permitted for use in certified organic farming

It is of specific value, if a BBF is approved for use in certified organic farming, since this sector is willing to pay a higher price for BBF's than conventional farming. Permission for marketing of fertilisers for use in certified organic production is given in each country, and a general principle is that it must be based solely on recycled nutrients.

- Organic matter content

Organic matter is associated with carbon (C), that typically constitutes about 40% of the organic matter content, which again characteristically constitute about 80% of the dry matter of organic wastes. Organic matter depletion of soils is threatening soil fertility in the entire EU. However, in the Baltic Sea Region, soils have generally higher levels of soil organic carbon, compared to soils in southern Europe (Montanarella et al. 2006).

Organic matter is especially well preserved in mechanical processing methods, whereas a part or all is lost by thermal treatments, whereas other processing types, including chemical (for instance acidification) and biological (for instance anaerobic digestion) also reduce the level of organic matter.

Farmers do appreciate if BBF's also contain organic matter, although this is seen as a secondary quality compared to the content of N and P nutrients.

- Nutrient availability

Nutrient availability, meaning that nutrients are readily available for plant uptake, is often affected by the processing.

In general, thermal processing reduces nutrient availability – see for instance Mackay et al. (2017) in the case of P. Some chemical processing has the same effect, for instance the practice of precipitating P with Iron or Zinc derivatives at wastewater treatment plants results in a relatively low P plant availability in wastewater sludge (Lemming, 2017).

Processing that means a higher nutrient availability in the resulting BBF includes anaerobic digestion in the case of N (see for instance Birkmose et al., 2007), and slurry acidification for both N and P (see for instance Fanguiero et al., 2015).

Given the aforementioned definition of a fertiliser, it is easy to understand that farmers according to Foged et al. (2025b) to a wide extent associates the quality of a BBF with its plant availability. Plant availability has a time dimension, and farmers expect that N and P nutrients are on a form whereby they are ready for uptake in plants. In general, this means the nutrients must be water soluble or extractable. Nutrients that are not readily available for the plants may be released in the soil matrix over time and first become available to the crop after months or years, and cannot meet crops' immediate demands for nutrients, although a fertiliser plan should take into consideration the second- and third-year effect of the use of organic fertilisers, despite the impreciseness this implies. Farmers do consider mineral fertilisers as "the golden standard", where they can expect that virtually all the fertilised N and P nutrients can be found in the harvested crop (unless negatively affected by unfavourable soil parameters, such as acidic or alkaline soils).

Nutrient availabilities are comparable to those of mineral fertilisers for BBF's, which can be categorised as inorganic nutrient concentrates, comprising for instance Ammonia Sulphate Solution (ASS), which alone contain traces of organic material. The higher the organic content of a BBF is, the lower will the plant availability of N and P be, and the processing can as mentioned also affect the plant availability.

- Concentration of unwanted substances

The concentration of unwanted substances like heavy metals, pathogens, plastics and various chemicals is often higher in BBF's with higher nutrient concentration, compared to the influent organic wastes. The increase is typically higher than a linear and 1:1 correlation, since the processing often mean a loss of N and P apart from water and organic matter (Foged et al. 2011).

The presence of unwanted substances is much related to the source, the type of influent organic wastes. The most problematic waste types are those that are based on wastewater, but manures from especially pig and poultry may also contain heavy metals used as feed additives, as well as chemical residues of for instance veterinarian medicine. For food wastes from supermarkets, a main problem is the plastic packaging.

Some processing reduces the content of unwanted substances, such as anaerobic digestion which reduce the content of weed seeds and agents of contagious diseases. Also, thermal processing reduces or eliminate organic, unwanted substances in the material, such as phenols and PCB.

Being the most troublesome organic waste type, not least in connection to field spreading for fertilisation, wastewater sludge is the waste type that has been most extensively considered and regulated. Wastewater sludge is on this background defining minimum standards in relation to unwanted substances for all types of organic wastes used for fertilisation in raw or processed form, since the logics are that these quality standards are universal.

Table 1 lists the heavy metals and their limit values given by the EU's Sewage Sludge Directive (SSD)<sup>9</sup>.

Table 1: Limit values given by the Sewage Sludge Directive for heavy metals in sewage sludge used for fertilisation. The Directive mention these limits can be exceeded by Member States if considered safe for growing feed for animals.

Contaminant	Limit value, mg/kg dry matter
Copper	50-140
Zinc	150-300
Cadmium	1-3
Nickel	30-75
Lead	50-300
Mercury	1-1.5
Chromium	Not defined

The SSD is from 1986, meaning rather old, and the Directive has not hindered a great concern for the safety of using wastewater sludge for fertilisation. It gives therefore meaning

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<sup>9</sup> <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31986L0278>

to consider whether the unwanted substances and their limit values that are regulated by the SSD are still relevant, not least in a BSR perspective.

Table 2 shows the contaminants considered and the associated limit values given by the Danish sludge ordinance<sup>10</sup> (DSO).

It is furthermore emphasised that the DSO regulates the following issues of principal character:

- Article 2 clarifies that the scope is wider than wastewater sludge: “The ordinance covers waste from households, institutions and companies, including biologically treated waste, process wastewater and sewage sludge, to the extent that the waste is intended to be used for agricultural purposes.”
- Article 7 says that the considered contaminants and associated limit values shall be respected and that the material “must not contain significant amounts of other environmentally harmful substances.” This means that those responsible for production or distribution of the fertiliser product must seek permissions and clarify the safety of using the product in case they have knowledge to the existence of such other environmentally harmful substances.
- Article 9 rules that in case several waste types are mixed, analyses of these must be made before mixing, and each of the waste types must have values under the given limits. It is with other words not possible to make a waste legal to use for fertilisation by using of the dilution principle.
- Article 21: Some more lenient rules apply in the case the wastes are used for co-digestion with livestock manures, which can be done up to 25% of the influent amount counted on dry matter basis.
- Article 26: Waste materials must not be spread on soils that are already contaminated with heavy metals.

*Table 2: Contaminants considered, and the associated limit values given by the Danish Sludge Ordinance.*

#	Group	Type	Main contaminants	Limit value
1	Heavy metals	Heavy metals	Cadmium	0.8 mg/kg DM and 100 mg/kg P
2			Mercury	0.8 mg/kg DM and

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<sup>10</sup> <https://www.retsinformation.dk/eli/ta/2018/1001>

## Suggested standards for fertilisers to sustainably recycle nutrients

#	Group	Type	Main contaminants	Limit value
				200 mg/kg P
3			Lead	120 mg/kg DM and 10,000 mg/kg P
4			Nickel	30 mg/kg DM and 2,500 mg/kg P
5			Chromium	100 mg/kg DM
6			Zinc	4,000 mg/kg DM
7			Copper	1,000 mg/kg DM
8	Environmentally hazardous substances	LAS: Linear alkylbenzene sulfonates		1,300 mg/kg DM
9		PAH: Polycyclic aromatic hydrocarbons.	$\Sigma$ PAH = $\Sigma$ Acenaphthene, Phenathrene, Fluorene, Fluoranthene, Pyrene, Benzfluoranthenes (b+j+k), Benz(a)pyrene, Benz(ghi)perylene, Indeno(1,2,3- cd)pyrene.	3 mg/kg DM
10		NPE: Nonylphenol (+ethoxylates)	NPE includes the substance nonylphenol itself and nonylphenol ethoxylates with 1-2 ethoxy groups.	10 mg/kg DM
11		DEHP: di(2-ethylhexyl)phthalate		50 mg/kg DM
12		PCB	PCB28, PCB52, PCB101, PCB118, PCB138, PCB153 and PCB180.	0.2 mg/kg DM
13	Pathogens	Microbes	Salmonella E-coli ..	No specific limit values given, but requirements to hygenisation are specified in relation to different materials and intended use.
14		Virus		
15	Impurities	Composite material		Generally, the limit is

#	Group	Type	Main contaminants	Limit value
16		Packaging material	Plastics	0,5% on a dry matter basis, and the particle sizes must be under 2 mm.
17		Microplastics	Micro plastics	

Table 2 is alone concerned about information of relevance for professional crop production, not for instance private gardening, and alone for products used for fertilisation, and not for instance for compost or other materials spread on fields for other purposes than fertilisation.

It is noted that some limit values are tighter in the SSD compared to the Danish DSO, such as for Zinc, whereas limit values are higher in other cases, such as for Cadmium. Both the SSD limits given in Table 1 and the DSO limits given in Table 2 differ from limits given by the FPR (Product Function Category: Organic fertiliser).

The below textbox provides some detailed examples of the current limit values, using Zn and Cd as examples. It is seen from these examples that in some cases, it is allowed to spread 1.5 kg Zn per ha per year, while after other regulations up to 20 kg Zn per ha per year. The examples assume the soil health is concerned about the root layer depth, which for most crops is 30 cm.

### Examples of current limit values

Healthy soils are according to EUSO containing less than 435 kg Zinc and 4.35 kg Cd per ha

For Zinc (Zn) and Cadmium (Cd), EUSO has defined a threshold for healthy soils of 100 mg/kg for Zn and 1 mg/kg for Cd<sup>1</sup>. Considering that the density of soil averagely is 1.45 (with a variation depending on the soil texture class from 1.30 for silt to 1.60 for clay loam). Using the average density of 1.45, the root level soil of 1 ha weighs 4,350 tonnes if the root depth of the plants is 30 cm. Given the mentioned thresholds, the amount of Zn in 1 ha soil should be under 435 kg, and the amount of Cd under 4,35 kg for the soils to be healthy.

Normal dosing of sludge with 25% dry matter (DM) is 15-20 ton per ha, normal dosing of pig slurry is 30 tonnes per ha, and normal dosing of Di Ammonium Phosphate (DAP) with 100% DM is 150 kg per ha

According to EU's Sewage Sludge Directive, sludge may contain up to 300 mg Zn per kg DM and up to 3 mg Cd per kg DM. With normal dosing rates, this would supply the field with up to (20 tons per ha \* 25% DM \* 300 mg Zn per kg DM =) **1.5 kg Zn per ha**. Likewise, it will supply the field with up to **15 grammes of Cd per ha**. It would thus take a minimum of 290 years of sewage sludge fertilisation to exceed the threshold for healthy soils with respect to Zn and Cd.

According to the Danish Sludge Ordinance, it is possible to spread sludge with up to 4,000 mg Zn per kg DM and up to 0.8 mg Cd per kg DM. With normal dosing rates, this would supply the field with **20 kg Zn per ha** and **4 grammes of Cd per ha**. It would take a minimum of 22 years for Zn and more than 1,000 years for Cd to exceed the thresholds for healthy soils.

According to EU's Fertilising Products Regulation, organic fertiliser (like sludge) can contain up to 1.5 mg per kg DM of Cd, while inorganic fertilisers like DAP may contain up to 60 mg/kg phosphorus pentoxide (P<sub>2</sub>O<sub>5</sub>). No limits are given for Zn. With normal dosing rates, this would supply the field with up to **7.5 grammes of Cd** in case of organic fertiliser and  $68 * 60 \text{ mg} =$  **4 grammes of Cd per ha** in case of inorganic fertiliser. It would take a minimum of 580, respectively more than 1,000 years for Cd to exceed the thresholds for healthy soils.

For pig slurry, according to three examples in AgroTechnologyATLAS (<https://www.agrotechnologyatlas.eu/manures>), an average content of Zn is 64.38 grammes per ton. With a normal dosing, this means a field would be supplied with **1.9 kg Zn per ha**. It would thus only take about 230 years of fertilisation with pig slurry before a soil containing zero Zn would turn into an unhealthy status. According to Tella et al. (2023), boiler excreta contain even higher levels of Zn.

- Ease of handling

Farmers are very clear, when it comes to handling of BBF's. They must be feasible for handling in conventional ways, which again means as for mineral fertilisers.

The material must be possible to store like mineral fertilisers, generally meaning in big bags that can be placed outside or in an uninsulated building, that the material is stockable, would neither leak or develop heat, and not give off strong odours or attract rodents. It should not be required to invest in specific storage facilities. Of course, liquid BBF's should be possible to store alike liquid mineral fertiliser, which generally means in IBC tanks for smaller quantities and polytanks for larger quantities.

Field spreading shall be possible without a requirement to invest in new spreading equipment, generally meaning that spreading must be possible with conventional mineral fertiliser spreaders, solid manure spreaders, slurry tankers or sprayers (for liquid qualities). It is of course acceptable that the spreading equipment must be calibrated against the physical properties and chemical composition of the given BBF.

- Social economy

The CiNURGi project has analysed 11 cases of bio-based fertiliser productions (Foged et al. 2025a), each of them being value chains comprising i) collection of organic wastes, ii) processing of the organic wastes into bio-based fertilisers, and iii) distribution of the resulting BBF.

The results shows that BBF nutrients generally comes with a considerably higher social cost than nutrients in conventional chemical fertilisers, but with substantial variation, among other due to the policy context. Social costs comprise the costs for collecting and processing the organic wastes and distribution of the resulting BBF, as well as the capitalised value of the net impact on nutrient loss and greenhouse gas (GHG) emissions, compared to the baseline situation. A part of the higher cost of BBF's, compared to mineral fertilisers, is due to complications with channelling back the social value of emission reductions to the value chain owners.

### 3: Suggested standards for bio-based fertilisers

Table 3 lists the key aspects that are mentioned in the previous section 2, evaluates whether these should be included in minimum quality standards for BBF's, and outlines suggested standards.

*Table 3: Key aspects in relation to valuation of bio-based fertilisers, their relevance and proposed minimum quality standards.*

#	Aspect	Relevance as a minimum standard, N/Y	Comments
1	High nutrient concentration, N and/or P	Y	The proposal is based on the EOM principle as used by Veeken et al. (2017), but modified to be based on one criterium, which includes both N and P, in plant available form. See section 3.1 for the proposed standard.
2	Analysed, declared and documented quality	Y	There should be an exception for BBF types with constant quality, such as nutrient concentrates like ASS and struvite. Requirements to declared content should follow that given by the FPR for organic fertilisers as explained in detail in section 3.2.
3	Stable quality	N	It would be an advantage if stable qualities could be promised, but most BBF's are based on organic wastes of varying quality.
4	Permitted for use in certified organic farming	Y	It is an advantage if a BBF is permitted for use in certified organic production, since this increases the market and the value of the BBF. However, this aspect is not suitable for being a general standard, since many BBF's are produced by use of added chemicals, including non-recycled N and P nutrients.  Fertilisers approved for use in certified organic farming is already given in Annex II of Commission Implementing Regulation (EU) 2021/1165 <sup>11</sup> , so in this way, a standard is already existing, and it is suggested that suppliers on a voluntary basis inform on the label, whether the product is listed in the mentioned Regulation – see section 3.2.

<sup>11</sup> [https://eur-lex.europa.eu/eli/reg\\_impl/2021/1165/oj/eng](https://eur-lex.europa.eu/eli/reg_impl/2021/1165/oj/eng)

## Suggested standards for fertilisers to sustainably recycle nutrients

#	Aspect	Relevance as a minimum standard, N/Y	Comments
5	Organic matter content	Y	<p>The suggested standard that distinguishes bio-based fertilisers from soil improvers comprise a required maximal ratio of Effective Organic Matter (EOM) to the amount of plant available N + P.</p> <p>However, any fixed standard for organic matter content of BBF's cannot be demanded, since this varies both within and between BBF types.</p> <p>It is suggested that suppliers on a voluntary basis inform about the organic matter content as well as the humification coefficient on the label. See section 3.2.</p>
6	Nutrient availability	Y	<p>The nutrient availability of BBF's shows a wide variation, and no minimum value can be determined. Users of BBF's must in general accept lower N and P plant availability, especially for BBF's containing organic matter.</p> <p>It is recommended that suppliers on a voluntary basis inform about the nutrient availability determined by field trials carried out by impartial organisations for guidance of the farmers to enable that their fertilisation meets the crop demands for nutrients. See section 3.2.</p> <p>It is also recommended that producers of BBF's use processing methods that do not reduce N and P availability.</p>
7	Limit values for unwanted substances	Y	<p>It is fundamental for trusting that BBF's do not harm soil fertility and sets the environment, biodiversity, human health etc. at risk. However, it is relevant with a paradigm shift so that Allowed Field Spreading amounts (AFS's) are defined, and so that already contaminated soils may not be added more pollutants, since the potential hazard of pollutants depends on the concentration in the nature, not in the bio-based fertiliser or other material that is spread. See section 3.3.</p>
8	Ease of handling	Y	<p>It is given the diversity of BBF's impossible to set meaningful standards.</p> <p>Distributors should voluntarily inform buyers in which way the BBF in question is stored, transported and field-spread, and the crop farmer can decide where this is acceptable.</p>

#	Aspect	Relevance as a minimum standard, N/Y	Comments
9	Social economy	Y	<p>BBF's are marketed with different prices, reflecting differences in production costs and nutrient content.</p> <p>Farmers willingness for using BBF's would in general be improved by standards as outlined, having the aim to give higher trust to the overall value of the BBF's.</p> <p>Foged et al. (2025a) found that 11 value chains for production of bio-based fertilisers from organic wastes in average only increased nutrient recycling with 28%, ranging from -61% to 100%, indicating variability in nutrient retention during processing. The average direct emission reduction impact (DERI) was 1.4 t CO<sub>2</sub>-equivalent per 1,000 kg of recycled N and P, with a range from -21.1 to 22.5 t CO<sub>2</sub>-equivalent, highlighting differences in transport and energy demands. The guiding social cost per recycled kg of N and P averaged €2.50, but varied widely between -€4.61 and €20.66, depending on value chain configuration. The comparable price for N + P in mineral fertilisers is €1.43 per kg if calculated in the same way, including climate impact costs. Nutrient concentration in BBFs compared to raw organic wastes also varied significantly, with ratios ranging from 1 to 422. These modest performances of BBF production were realised as a result of analysing a Baltic Sea wide search for the best examples of BBF production and a longlisting of the 11 assumingly best performing cases out of 24 cases in total.</p> <p>Lower BBF prices would be enabled by mechanisms to channel the capitalised values of the net impact of BBF's on environmental pollution and GHG emissions, and it is proposed to develop such mechanisms. Production of BBF's should alone be done if the environmental and climate impacts for the society are lower than those of the baseline way of dealing with the organic wastes in question. See section 3.4.</p>

### 3.1: Proposed standard for ratio between effective organic matter and available N + P in bio-based fertilisers

The algorithm proposed by Veeken et al. (2017) for distinguishing between an organic fertiliser and a soil improver is in line with general perceptions, but has some inherent inadequacies, as mentioned in section 1.2. It is therefore suggested to adjust the algorithm so that it is universally

applicable, also for BBF's that alone contain either N or P, and so that the EOM ratio is set to N + P, in both cases on plant available forms.

Furthermore, since there is a need for clarification of the term "nutrient-rich", and since some materials, for instance manure based digestates, can be considered both an organic waste and a bio-based fertiliser, it is suggested that the following algorithm is applicable for determining whether a material is either a bio-based fertilisers or a nutrient-rich waste:

► Bio-Based Fertilisers and Nutrient-Rich Wastes:  $(N_A + P_A) \times 20 - EOM > 0$

Where:

- $N_A$  is plant-available N, in general the same as  $NH_4-N$ , measured in Kg per ton.
- $P_A$  is plant-available P, in general water extractable P, measured in Kg per ton.
- EOM is Effective Organic Matter, found by multiplying the organic matter with a humification coefficient (HC), measured in Kg per ton.

Consequently, soil improvers and nutrient-poor wastes are defined by the following algorithm

► Soil Improvers and Nutrient-Poor Wastes:  $(N_A + P_A) \times 20 - EOM < 0$

Figure 2 shows a plot of EOM and  $(N_A + P_A)$  datasets. The used datasets are listed in Annex 1 and comprises the 27 datasets provided by Veeken et al. (2017), 19 relevant examples from AgroTechnologyATLAS, and wheat straw, in total 47 datasets. A few datasets have so extreme values that they are plotted outside the area. The line in Figure 2 represents the division between nutrient-rich wastes or bio-based fertilisers, which are under the line, and nutrient-poor wastes or soil improvers, which are plotted over the line. The figures near the points represents the result of the algorithm. The light green area around the line illustrates that there may be cases of bio-based fertilisers or nutrient-rich wastes that also have high secondary function as soil improver or is a nutrient-poor wastes with a relatively high nutrient content, and opposite – algorithm results of these datasets are close to zero.

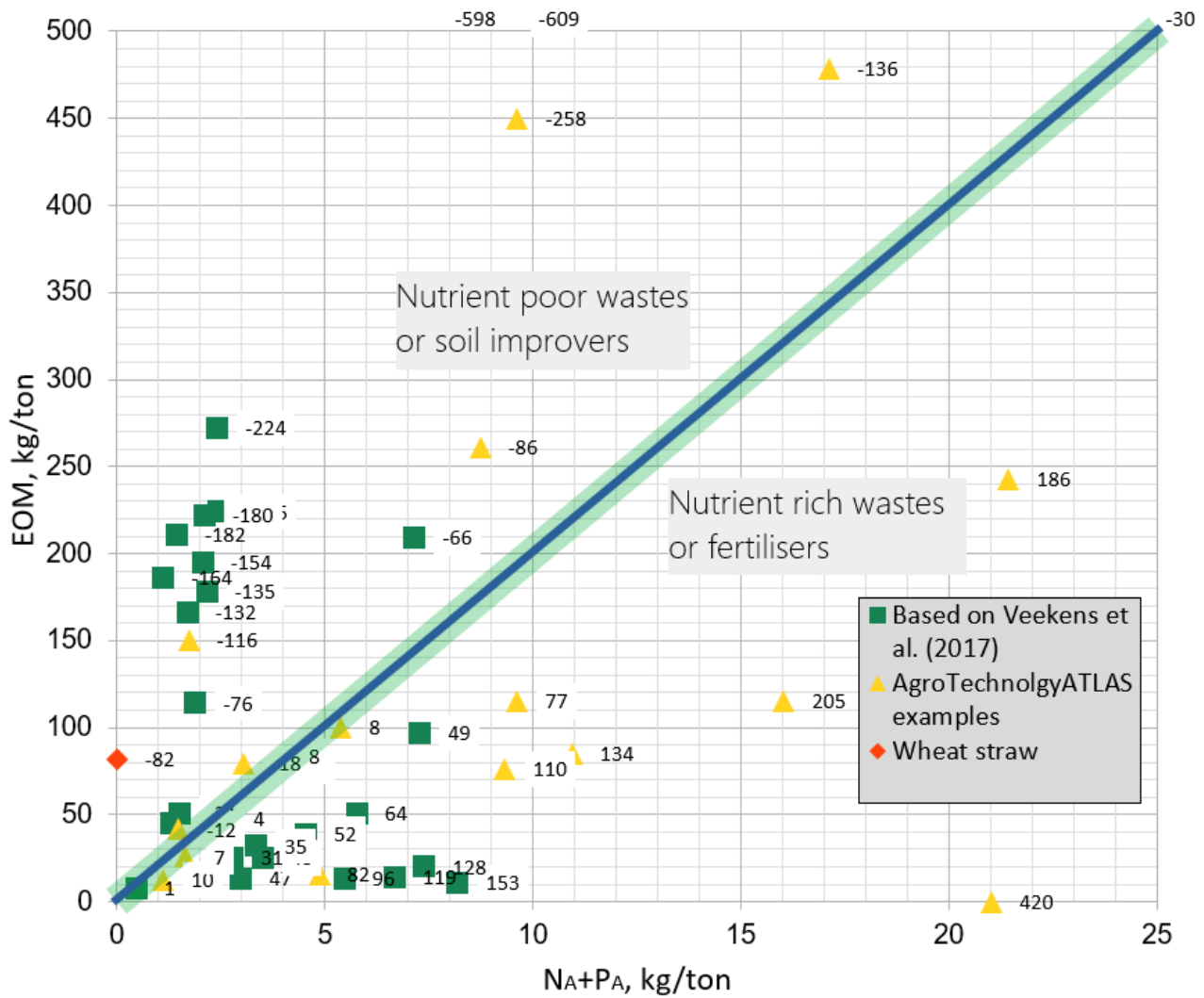


Figure 2: Plot of datasets of Effective Organic Matter content and readily available N + P, the line representing the division between nutrient-poor wastes or soil improvers and nutrient rich wastes or bio-based fertilisers. Used dataset are listed in Annex 1.

The specific type of material behind the points can be seen from Annex 1.

The relevance of the algorithm for distinguishing between nutrient-rich organic wastes or bio-based fertilisers and nutrient-poor organic wastes and soil improvers is proven by the fact that materials that are indeed seen as nutrient-poor or soil improvers, such as composts, biochars and straw, gives a clear negative result in the equation. Opposite, materials that are considered as fertilisers or nutrient rich wastes, such as livestock manure slurries and digestates, comes generally out with a positive result.

Exceptions are for instance some datasets provided by Veekens et al. (2017). However, it is questioned whether the datasets include some mistakes since it is not clear how some examples of cattle slurry have a humification coefficients of 0.40, while other examples of cattle slurry have humification coefficients of 0.75. Likewise, it is considered a mistake that one of the datasets are provided with a humification coefficient of 1.23.

## 3.2: Declaration of chemical content

It is recommended that BBF's are labelled in accordance with EU's FPR as specified in Annex III of the Regulation, as indicated for PFC 1, keeping in mind that BBF's may belong to organic fertilisers (PFC 1 A), Organo-mineral fertiliser (PFC 1 B), or Inorganic fertiliser (PFC 1 C).

Otherwise, it is recommended that the declaration / labelling contain some voluntary information as specified above concerning approval for use in certified organic farming, the Humification Coefficient for content of Organic Matter, the N and P plant availability, and guidance on handling (transport, storage and spreading) – see Figure 3.

### Bio-based fertiliser

1. Compulsory information according to Annex III of the FPR.
2. Voluntary information: Approved for certified organic farming in accordance with Annex II of Commission Implementing Regulation (EU) 2021/1165.
3. Voluntary information: Assumed Humification Coefficient with reference to scientific evidence for bio-based fertilisers produced with similar processing technology.
4. Voluntary information: N and P nutrient availability, in general the amount of mineralised N and the amount of water extractable P, with reference to field trials carried out by impartial organisations.
5. Voluntary information: Short guidance about requirements to transporting and storage, which is much related to the physical form of the BBF, and in addition guidance on field-spreading of the BBF, such as suitable spreading equipment.

*Figure 3: Recommended labelling / declaration of traded BBF's.*

The voluntary information can be agreed with the BBF suppliers or their branch organisation, alternatively required via national legislation.

## 3.3: Proposed standards related to unwanted substances

Limit values for unwanted substances in fertiliser products are regulated in EU's Sewage Sludge Directive (SSD) from 1986 and in EU's much newer Fertilising Products Regulation (FPR) from 2019. In the meantime, EU has also launched a Soil Mission<sup>12</sup>, with one of its eight specific objectives being to reduce soil pollution and work for restoring polluted soils. More than 60% of all EU soils are unhealthy, including 89% of agricultural soils, and a mapping tool makes it possible to look up details about locations and indicators<sup>13</sup>, which includes Zinc, Arsenic, Cadmium, Mercury and

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<sup>12</sup> [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en)

<sup>13</sup> <https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/>

Copper, among 19 indicators for soil health. An important indicator in relation to environmentally hazardous substances in BBF's is "Soil biodiversity", since these may pose a risk for soil organisms.

Of the unwanted substances listed in Table 2, most are related with wastewater, whereas pig and poultry manure mainly are accountable for Zinc and Copper, and food wastes from supermarkets is the main source of impurities.

These differences in limit values, illustrated with examples of allowed spreading of Zn and Cd in different fertiliser types, gives reason for reconsidering these since it seems illogical with so widely different limit values are established in the legislation. Assuming that the influence of Zn on soil health is independent of the material the Zn is contained in, whether it is sewage sludge, inorganic fertiliser, pig slurry or poultry manure, and likewise independent of the concentration of the pollutant in the material it is contained within. It would therefore be natural to change regulations to consider the capacity of soils to receive pollutants. This is the way air pollution and water pollution are regulated. Since EU soils are mapped for their content of pollutants, it would also be relevant to avoid further pollution of already unhealthy soils.

Based on the above are recommended the following standards:

- ▶ It shall be prohibited to fertilise with wastewater sludge or wastewater-based BBF's at areas that are appointed via the EUSO dashboard as polluted with heavy metals or has an unhealthy soil biodiversity.
- ▶ It shall be prohibited to fertilise with pig and poultry manure or processed products thereof at areas that are appointed via the EUSO dashboard as polluted with Zinc or Copper.
- ▶ Food wastes in packaging material shall be collected separately and the packaging material separated before the food waste nutrients can be recycled to the food chain as BBF. Impurities must be < 0.5% and the particle size < 2 mm.

Further, since BBF's are field spread in varying amounts per ha, dependent on the N and P content, it is relevant to regulate the supply of pollutants per ha rather than the level of unwanted substance per weight unit of the organic waste or BBF. For this is proposed the following standards are recommended:

- ▶ The EU Commission shall regulate the Allowed Field Spreading (AFS) at soils with pollution levels under the determined thresholds and therefore not being polluted with heavy metals or having an unhealthy soil diversity according to the EUSO dashboard, of the Table 2 defined list of unwanted substances, given in weight unit per ha. The principle must be that repeated field spreading up to the AFS limit will not cause threat to the soil health, considering the input of the unwanted substance as well as the assessed restoration (removal) via normal crop rotations.

HELCOM may recommend AFS coefficients for use in the Baltic Sea Region, which could be adopted for wider use in the EU.

### 3.4: Social economy

Based on the abovementioned information, including the findings of Foged et al. (2025) it is recommended as a standard that bio-based fertilisers are made from nutrient-rich wastes, and soil improvers only from nutrient-poor wastes according to the abovementioned definition, since production of soil improvers from nutrient rich wastes mean an almost entire loss of plant available N and P and in addition a loss of typically 50%+ of organic matter and C, and all losses happen at the cost of the environment and the climate. Figure 4 illustrates these recommended principles.

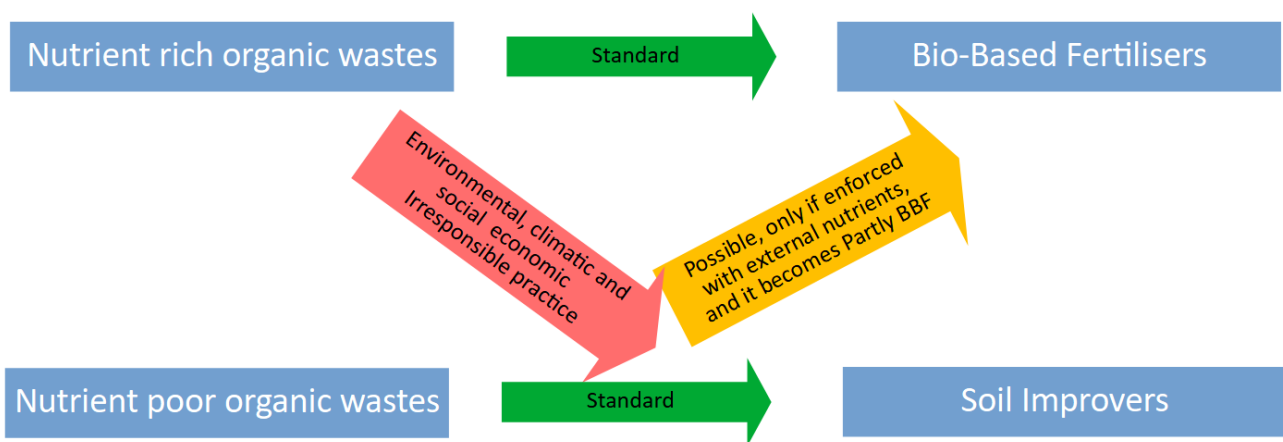


Figure 4: It is recommended that bio-based fertilisers always are produced from nutrient-rich wastes, and that nutrient rich-wastes are never used for production of soil improvers.

A general principle shall be that the capitalised value of environmental and climate impacts of BBF production must be positive.

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## Annex 1: Datasets used for Figure 2

	Dry matter, kg/ton	Organic Matter, kg/ton	HC, share of OM <sup>14</sup>	EOM, kg/ton	N-total, kg/ton	N-mineral, kg/ton	N-organic, kg/ton	P2O5, kg/ton	Estimated P availability, % <sup>15</sup>	Available P2O5, kg/ton	NA+PA, kg/ton	(NA + PA) * 20 - EOM, kg/kg
<b>Veekens et al. (2017)</b>												
Digested pig slurry	82	32	0,34	11	7,1	5,2	1,9	4,6	65	3,0	8,2	153
Pig slurry	57	43	0,33	14	7,1	4,6	2,5	4,6	45	2,1	6,7	119
Pig slurry	5	38	0,33	13	5,6	4,2	1,4	2,8	45	1,3	5,5	96
Pig slurry	83	56	0,36	20	8,6	5,5	3,1	4,2	45	1,9	7,4	128
Pig slurry	45	38	0,35	13	5,1	1,9	3,2	2,4	45	1,1	3,0	47
Solid pig manure	260	153	0,33	51	7,9	2,6	5,3	7,9	40	3,2	5,8	64
Cattle slurry	86	64	0,40	25	5,2	2,9	2,3	1,5	40	0,6	3,5	45
Digestate manure-energy crops	88	54	0,72	39	4,6	2,2	2,4	3,9	60	2,3	4,5	52
Digested cattle slurry	69	48	0,67	32	4,1	2,6	1,5	1,5	50	0,8	3,4	35
Sewage sludge	160	112	0,44	45	5,6	0,0	5,6	6,4	20	1,3	1,3	-19
Solid pig manure	299	230	0,42	97	10,7	3,6	7,1	9,2	40	3,7	7,3	49
Cattle slurry	80	63	0,75	47	3,9	2,1	1,8	1,7	40	0,7	2,8	9
Solid cattle manure	242	184	0,42	78	8,5	2,7	5,8	4,0	35	1,4	4,1	4
Digestate household waste	15	10	0,84	8	0,5	0,3	0,2	0,3	50	0,2	0,5	1
Cattle slurry	86	64	0,45	48	4,1	2,0	2,1	1,5	40	0,6	2,6	4

<sup>14</sup> Humification coefficients for wheat straw is based on Berti et al. (2016) and examples from AgroTechnologyATLAS are assessed on basis of that and the humification coefficients provided by Veekens et al. (2017).

<sup>15</sup> The phosphorus availability is assessed roughly on basis of information provided by Mackay et al. (2020), Pedersen et al. (2017), Elsgaard et al. (2022) and Lemming (2017).

## Suggested standards for fertilisers to sustainably recycle nutrients

	Dry matter, kg/ton	Organic Matter, kg/ton	HC, share of OM <sup>14</sup>	EOM, kg/ton	N-total, kg/ton	N-mineral, kg/ton	N-organic, kg/ton	P <sub>2</sub> O <sub>5</sub> , kg/ton	Estimated P availability, % <sup>15</sup>	Available P <sub>2</sub> O <sub>5</sub> , kg/ton	NA+PA, kg/ton	(NA + PA) * 20 - EOM, kg/kg
Cattle slurry	85	68	0,75	51	4,5	0,7	3,8	2,0	40	0,8	1,5	-21
Solid cattle manure	233	186	0,75	140	8,1	2,4	5,6	3,9	35	1,4	3,8	-64
Solids of digestate manure-energy crops	253	170	1,23	209	8	1,5	6,5	11,3	50	5,7	7,2	-66
Solid cow manure	267	152	0,75	114	5,3	0,9	4,4	2,8	35	1,0	1,9	-76
Bio-waste compost	667	249	0,90	224	12,7	0,5	12,2	6,5	30	2,0	2,5	-175
Green waste compost	625	188	0,95	178	7,2	0,0	7,2	6,1	35	2,1	2,2	-135
Bio-waste compost	661	217	0,90	195	7,6	0,8	6,8	4,2	30	1,3	2,1	-154
Bio-waste compost	575	302	0,94	272	10,1	0,0	10,0	7,9	30	2,4	2,4	-224
Bio-waste compost	638	247	0,94	222	9,4	0,6	8,8	5	30	1,5	2,1	-180
Green waste compost	594	185	0,90	166	5,3	0,5	4,8	3,4	35	1,2	1,7	-132
Green waste compost	623	234	0,94	211	7,4	0,3	7,1	3,4	35	1,2	1,4	-182
Green waste compost	578	194	0,96	186	7,2	0,1	7,1	2,9	35	1,0	1,1	-164
<b>Various organic wastes and bio-based fertilisers</b>												
Wheat straw	850	819	0,70	82	4,2	0,0	4,2	2,1	0	0,0	0,0	-82
<b>AgroTechnologyATLAS examples</b>												
Whey (4)	70	63	0,20	13	0,5	0,1	0,4	1,3	80	1,0	1,1	10
Flotation sludge (3)	80	64	0,40	26	3,5	0,3	3,2	3,3	40	1,3	1,7	7
Stomach content, pigs (2)	130	104	0,40	42	3,9	0,5	3,4	2,3	45	1,0	1,5	-12
Fish silage (14)	900	810	0,30	243	29,0	19,6	9,4	2,3	80	1,8	21,4	186
Fibre fraction (8)	220	176	0,45	79	3,8	2,0	1,8	3,0	35	1,0	3,0	-18
Bioenergie-Region Südoldenburg pig slurry solid fraction (7)	279	250	0,40	100	8,2	3,0	5,2	6,0	40	2,4	5,4	8
Bioenergie-Region Südoldenburg pig slurry solid fraction (1)	275	190	0,40	76	9,8	3,0	6,8	15,8	40	6,3	9,3	110
Fibre fraction (10)	360	288	0,40	115	11,6	4,0	7,6	16,0	35	5,6	9,6	77
Solid fraction from a mechanical separator (114)	283	212	0,40	85	11,8	5,4	6,4	15,8	35	5,5	10,9	134
Fibre fraction (2)	360	288	0,40	115	11,8	5,6	6,2	29,8	35	10,4	16,0	205
Biochar from swine pig (Ro et al., 2010) (55)	966	830	0,99	822	31,5	0,0	31,5	158,3	25	39,6	39,6	-30
Biochar from chicken litter (Ro et al., 2010) (54)	960	806	0,99	798	26,6	0,0	26,6	37,8	25	9,5	9,5	-609
Biochar from poultry litter (starter turkey) (Agblevor et al. 2010) (53)	960	754	0,99	746	17,5	0,0	17,5	29,8	25	7,4	7,4	-598
Biochar from poultry litter (broiler) (Agblevor et al. 2010) (52)	970	455	0,99	450	16,8	0,0	16,8	38,5	25	9,6	9,6	-258

## Suggested standards for fertilisers to sustainably recycle nutrients

	Dry matter, kg/ton	Organic Matter, kg/ton	HC, share of OM <sup>14</sup>	EOM, kg/ton	N-total, kg/ton	N-mineral, kg/ton	N-organic, kg/ton	P <sub>2</sub> O <sub>5</sub> , kg/ton	Estimated P availability, % <sup>15</sup>	Available P <sub>2</sub> O <sub>5</sub> , kg/ton	NA+PA, kg/ton	(NA + PA) * 20 - EOM, kg/kg
Ash (7% of the input) (30)	998	0	1,00	0	0,1	0,0	0,1	210,1	10	21,0	21,0	420
Acidified pig slurry (25)	55	44	0,35	15	4,3	3,2	1,1	2,2	75	1,6	4,9	82
Compost from co-digested cow slurry + organic wastes (Giro, 2010) (56)	220	167	0,90	150	6,6	0,7	6,0	2,7	40	1,1	1,7	-116
Compost from a centralized composting plant of cow manure (Juncasa, Catalunya, Spain) (112)	889	532	0,90	479	26,3	3,0	23,3	35,2	40	14,1	17,1	-136
Compost-Cow manure (Fervosa, Spain) (130)	512	290	0,90	261	11,9	4,0	7,9	11,8	40	4,7	8,7	-86



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This report, produced in connection with Task A1.2 of the Interreg Baltic co-financed CiNURGi project, presents "Suggested standards for fertilisers to sustainably recycle nutrients".

The report proposes some definitions to delineate the scope for the suggested standards, which shall have the purpose to raise the valuation of bio-based fertilisers and crop producers' willingness to pay for them.

The concrete suggested standards include notably an algorithm whereby bio-based fertilisers and nutrient rich wastes are distinguished from soil improvers and nutrient poor wastes. A paradigm shift is furthermore proposed when it comes to the regulation of soil pollutants, which is suggested to happen on basis of Allowed Field Spreading amounts, and that spreading of more pollutant on soils that are already registered by the EU Soil Observatory as unhealthy for that pollutant shall be banned.

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