FertiCovery

D4.1 Fertilising products analysis and characterization.

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Summary

Summary of Deliverable

This deliverable presents a comprehensive and scientifically robust assessment of **25 nutrient recovery technologies** and their corresponding fertilising products developed within the FertiCovery project framework. The primary objective is to systematically characterize the **fertilizing products derived from secondary raw materials**, focusing on their agronomic value, composition, safety, and data availability.

The analysis covers a wide spectrum of recovered fertilising products, including:

- **Compost**
- **Digestate** (solid/liquid fraction)
- **Liquid ammonium nitrate/sulphate**
- **Mineral concentrate** (e.g liquid N containing products, digestates ammonium sulphate, ammonium nitrate)
- **Potassium salts**
- **Biostimulants** (amminoacid, humic substances)
- **Liquid organo-mineral fertilisers**
- **Struvite** (precipitated P)
- **Biochar**
- **Nitrogen enriched manure slurry**

For each category of fertilising product, a dedicated profile has been developed following a harmonized structure including:

- Macronutrient composition (N, P, K and related forms)
- Micronutrient content
- Presence of plant stimulants (e.g. humic substances, amino acids, microbial activity)
- Contaminants and safety indicators (heavy metals, organic pollutants, pathogens)
- Additional agronomic properties (e.g. pH, stability, nutrient availability)

A key strength of this deliverable is the **integration of multiple data sources**, including:

- data from technology provider questionnaires;
- data from technology provider datasets (e.g. laboratory analyses, certified data);
- data from technology provider websites and/or other projects websites;
- data from Ferticovery project specific analysis (carried out by PWR);
- data from technical reports and scientific literature.

This approach allows a clear evaluation of **data completeness across** technologies and category of fertilising product. Technologies such as struvite recovery and certain composting systems are supported by high-quality analytical datasets, whereas emerging or pilot-scale solutions (e.g. some biochar or nutrient concentration systems) show notable data gaps.

From a technical perspective, the deliverable demonstrates that:

- Nutrient recovery technologies can produce fertilising products with **comparable agronomic performance to conventional products**, particularly for nitrogen and phosphorus.
- Recovered products often show **low contaminant levels**, especially when based on controlled processes such as crystallization or thermal treatment.
- Carbon-based materials play a crucial role as **soil improvers**, enhancing nutrient retention, soil structure, and long-term carbon sequestration.

At the same time, the analysis identifies key challenges:

- **Heterogeneity of products** across technologies
- **Lack of standardized datasets** for several parameters (e.g. EC, microbiology, organic contaminants)
- Limited availability of **full-scale, long-term agronomic performance data**

Overall, this deliverable provides a **structured, transparent, and comparable dataset** on recovered fertilising products, supporting:

- future techno-economic and environmental assessments (WP4/WP5)
- identification of promising technologies for scale-up
- policy and regulatory discussions on secondary raw material-based fertilising products

The results highlight the strong potential of nutrient recovery technologies to contribute to a **circular and sustainable fertilising product system**, while also emphasizing the need for further data harmonization and validation.

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Abbreviations

DM – Dry Matter

FM – Fresh Matter

CFU – Colony Forming Units

CEC – Cation Exchange Capacity

EC – Electrical Conductivity

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1 Introduction

1.1 Objectives

The transition towards a circular economy in the agricultural sector requires the development and implementation of technologies capable of recovering nutrients from secondary raw materials and transforming them into safe and effective fertilizing products. Within this context, the FertiCovery project investigates a wide range of nutrient recovery technologies, including biological, chemical, and thermochemical processes, applied to diverse input streams such as biowaste, manure, digestate, industrial residues, and wastewater.

The resulting products span multiple fertilising products categories, including organic fertilising products, organo-mineral fertilising products, inorganic fertilising products, biostimulants, and organic soil improvers. These products differ significantly in terms of composition, nutrient availability, agronomic performance, and regulatory status. Therefore, a systematic and harmonized assessment is required to ensure comparability across technologies and to evaluate their potential contribution to sustainable nutrient management.

This deliverable provides a structured characterization of fertilizing products obtained from 25 selected technologies, focusing on their physicochemical properties, nutrient content, contaminant levels, and data availability. Particular attention is given to the alignment with the European Fertilising Products Regulation (EU Regulation 2019/1009), as well as to the identification of data gaps that may limit market uptake or regulatory compliance[1,2].

The main objective of this deliverable is to develop a comprehensive and harmonized dataset describing the characteristics of fertilising products derived from nutrient recovery technologies.

Specific objectives include:

- To **characterize the composition** of fertilizing products in terms of macronutrients (N, P, K), micronutrients, organic matter, and other relevant parameters.
- To **identify the presence of plant stimulants**, such as humic substances, amino acids, or beneficial microorganisms, where applicable.
- To **assess potential contaminants**, including heavy metals, organic pollutants, and pathogens, based on available analytical data.
- To **evaluate data availability and quality**, distinguishing between measured, estimated, and missing data.
- To **group technologies into coherent categories** (e.g. compost, digestate, struvite, ammonium salts, biochar) in order to facilitate comparison.
- To **assess alignment with EU Regulation 2019/1009**, including Product Function Categories (PFC) and Component Material Categories (CMC).
- To **identify key data gaps and uncertainties** that may affect regulatory compliance, agronomic performance, or scalability.

Ultimately, the deliverable aims to support further techno-economic and environmental analyses within the project and to contribute to the development of robust, market-ready nutrient recovery solutions.

1.2 Methodology

The methodology adopted in this deliverable is based on a multi-source data integration approach, combining project-specific analytical information with literature data and technical documentation provided by technology developers.

The assessment was carried out through the following steps:

1. **Data collection**
    - Collection of information from technology providers through structured questionnaires.
    - Compilation of analytical data from laboratory reports, certification schemes, and technical datasheets from technology providers (including their websites and/or other projects websites).
    - Compilation of analytical data from analysis carried out within Ferticovery project (by PWR).
    - Review of scientific literature and technical reports to complement missing information.
2. **Data harmonization**
    - Standardization of parameters across all technologies to ensure comparability.
    - Conversion of units and normalization of values where necessary.
    - Alignment of parameter definitions with the structure of the deliverable (macronutrients, micronutrients, plant stimulants, contaminants).
3. **Product categorization**
    - Grouping of technologies into categories based on the type of fertilising product produced (e.g. compost-based, digestate-based, mineral fertilising products, biochar).
    - Identification of common characteristics within each category.
4. **Regulatory assessment**
    - Mapping of each category to the relevant **PFC and CMC classes** under EU Regulation 2019/1009.
    - Preliminary evaluation of compliance based on available data (e.g. nutrient declaration, contaminant limits, hygienization requirements).

This structured approach ensures transparency, reproducibility, and consistency in the assessment of all technologies.

1.2.1 Data Quality and Limitations

Despite the extensive dataset collected, several limitations were identified during the analysis.

First, **data availability varies significantly across technologies**. Some products, such as struvite and certified composts, are supported by detailed analytical datasets, including nutrient composition and contaminant levels. In contrast, emerging technologies (e.g. certain biochar systems or nutrient concentration processes) often lack comprehensive characterization.

Second, **methodological heterogeneity** across data sources introduces uncertainties. Analytical methods, sampling procedures, and reporting formats differ between providers and studies, making direct comparison challenging in some cases.

Third, several parameters of interest, such as Electrical Conductivity (EC), detailed microbiological characterization, organic contaminants (e.g. microplastics, pharmaceuticals), are **rarely reported**, even for well-established products.

Finally, regulatory compliance assessment is sometimes limited by the absence of complete contaminant profiles, long-term agronomic performance data, and standardized product classifications.

These limitations are explicitly documented in the deliverable through the identification of data gaps. This approach ensures that conclusions are based on transparent assumptions and highlights areas where further research and data collection are required.

The ranges and mean values reported in the following tables are descriptive values derived from data and sources available for the product types considered in this deliverable. They should not be interpreted as statistically representative European averages for the entire CMC category. Where literature data are used, priority was given to European products, feedstocks and operating conditions whenever suitable information was available; however, the geographical scope depends on the individual source cited. Accordingly, comparisons with FERTICOVERY technologies should be interpreted at product-type level rather than as a comparison against a universal CMC benchmark.

2 Fertilizing products

2.1 List of fertilizing products

The initial list of fertilizing products and technologies considered in this deliverable is reported in Table 2.1.

Table 2.1 – List of fertilizing products

Technology #	Technology type	Main feedstock group	Specifics	Fertilizers products name	PFC	CMC
1	Anaerobic digestion	Bio-waste	Bio-waste and green waste	Compost from digestate solid fraction of biowaste	PFC3(A)	CMC3
2	Anaerobic digestion	Bio-waste	Bio-waste and green waste	Compost from digestate solid fraction of biowaste	PFC3(A)	CMC3
3	Anaerobic digestion	Bio-waste	Bio-waste and green waste	Compost from digestate solid fraction of biowaste	PFC3(A)	CMC5
4	Anaerobic digestion	Manure/ digestate	Pig manure	Solid fraction of digestate from manure Liquid fraction of digestate from manure Mineral concentrate (NK) from digested manure Potassium salts from digested manure	PFC1(C) -3(A)	CMC5, CMC15
5	Anaerobic digestion	Bio-waste	Food industry by-products; municipal bio-waste, garden waste	Solid fraction of digestate from livestock manure and agri-residues Liquid fraction of digestate from livestock manure and agri-residues	PFC1(A)-3(A)	CMC5
6	Anaerobic digestion	Bio-waste	Food waste	Matured solid fraction of digestate from biowaste	PFC3	CMC5
7	Composting	Bio-waste	Bio-waste, including food and garden waste	Compost from biowaste (without animal by-products)	PFC3(A)	CMC3
8	Composting	Bio-waste	Garden waste	Compost from garden waste	PFC3(A)	CMC3
9	Composting	Bio-waste	Bio-waste	Compost from municipal biowaste and garden waste	PFC3(A)	CMC3

10	Composting	Bio-waste	Herbaceous parts of branches, leaves, grass from gardens	Compost from green waste	PFC3(A)	CMC3
11	Fermentation Anaerobic digestion	Others	Potato residues	Solid fraction of digestate from livestock manure, agri-residues and potato residues	PFC1(A)	CMC5
12	Hydrolysis	Sludges	Solids from WWTP	Liquid organo-mineral fertiliser from sewage sludge	PFC1(A)	CMC11
13	Hydrolysis	Sludges	Sewage sludge	Liquid organo-mineral fertiliser from sewage sludge and food waste	PFC1(A)	CMC10
14	Hydrolysis	Others	Poultry feathers	Liquid organo-mineral fertiliser from poultry feathers	PFC1(B)	CMC10
15	Hydrolysis	Manure/digestate	Digestate from AD	Liquid organo-mineral fertiliser from digestate	PFC1(B)	CMC5, CMC10
16	Others	Manure/digestate	Animal manure, liquid fraction digestate	Nitrogen-enriched manure slurry from livestock manure and (digested) livestock manure	PFC1(B)	CMC5
17	Physical	Sludges	Municipal and industrial wastewater, digested sludge	Struvite from (digested) sewage sludge and sludges from potato and dairy industry	PFC1(C)	CMC12
18	Physical	Sludges	Sludge dewatering liquor, WWTP internal recycle streams	Struvite from (digested) sewage sludge	PFC1(B)	CMC12

19	Physical	Manure/digestate	Animal manure, sludge from industrial WWTP and other bio-wastes	Solid fraction of digestate from livestock manure and industrial biowaste Mineral concentrate (NK) from (digested) livestock manure and industrial biowaste	PFC3(A)-6	CMC5,
20	Physical	Manure/digestate	Liquid fraction of digestate	Solid fraction of digestate from livestock manure and industrial biowaste Mineral concentrate from digested livestock manure and agricultural residues	PFC6	CMC10, CMC15
21	Physicochemical	Manure/digestate	Liquid fraction of manure or digestate	Liquid ammonium nitrate from (digested) manure and industrial wastewaters Liquid ammonium sulphate from (digested) manure and industrial wastewaters	PFC1(C)	CMC15
22	Physicochemical	Manure/digestate	Pig manure and digestate	Liquid ammonium sulphate from (digested) livestock manure	PFC1(A)	CMC15
23	Thermochemical	Lignocellulosic biomass	Biomass residues, other woody biomass	Biochar from woody biomass and agricultural residues	PFC3(A)	CMC14
24	Thermochemical	Lignocellulosic biomass	Agricultural and forestry residues	Biochar from woody biomass	PFC3(A)	CMC14
25	Thermochemical	Bio-waste	Herbaceous parts of branches, leaves, grass from gardens	Biochar from woody biomass	PFC3(A)	CMC14

3 Fertilizing products analysis and characterization – CMC3

Category CMC3 – COMPOST → Related products/technologies n° 1, 2, 7, 8, 9 and 10.

3.1 Nutrient content

The average values in terms of macronutrients for fertilizing products belonging to the CMC3 category are included in Table 3.1.

Table 3.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	Range: 41.2-53.2% DM; mean ≈47.44% DM; typical of stabilized compost derived from lignocellulosic and organic residues[3,4,5,6,7]	%
2	N_{total}	Range: 0.74-2.3 DM; mean ≈1.27 DM; mainly organic nitrogen fraction[3,4,5,6,7]	%
3	$N_{organic}$	Range: 70–90% of total N; dominant form after compost maturation[3]	%
4	N available (NH_4-N, NO_3-N)	NH_4-N very low → Range: 0.0142-2 % DM; mean ≈1.50% DM; NO_3-N dominant after maturation → Range: 0.0007-4% DM; mean ≈2.6669% DM; indicates nitrification[3,5]	%
5	P_{total}	Range: 0.26-2.2% DM; mean ≈0.68% DM; conserved during composting[3,4,5,6,7]	%
6	Available P_2O_5	Range: 0,29% - 1,38% DM; mean ≈ 0.52% DM; increases with humification; not always analytically reported[3,4,5,6,7]	%
7	K_2O	Range 0.46-2.2% DM; mean ≈0.96% DM; largely conserved[3,4,5,6,7]	%
8	CaO	Range: 1.72-7.6% DM; mean ≈3.48% DM; ash-derived fraction[3]	%
9	MgO	Range: 0.29-0.88% DM; mean ≈0.534% DM[5]	%
10	S	Range: 8.18-12.86% DM; mean ≈9.816% DM[7]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC3 category are included in Table 3.2.

Table 3.2 - Micronutrients

#	Parameter	Value	Unit
1	B	Range: 15-68 DM; mean: 27.6 DM Trace levels; typically <50 mg/kg DM; rarely reported analytically[4,6,8]	mg/kg
2	Cu	Range: 16-51 DM; mean: 27.57 DM Range: 20–150 mg/kg DM; mean ≈ 60 mg/kg DM; dependent on feedstock[4,6,8]	mg/kg
3	Fe	Range: 3132–6830 DM; mean ≈ 4872.8 DM[4,6,8]	mg/kg
4	Mn	Range: 800–1200 DM; mean ≈ 970 DM[4,6,8]	mg/kg
5	Zn	Range: 83-170; mean: 125.3 Range: 50–400 DM; mean ≈ 150 DM[4,6,8]	mg/kg

3.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC3 category are included in Table 3.3.

Table 3.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Present at low–moderate levels from protein degradation; not systematically quantified[4,5]	%
2	Humus substances	Range: 12.2-28.9%; mean ≈ 16.19% High; compost represents advanced humification stage; humic and fulvic acids dominant[3,4,5]	%
3	Other stimulants	Presence of humic-like substances improving nutrient uptake and root growth[3,5]	%
4	Plant growth stimulating microorganisms	Range: 10^5–10^7 CFU/g; active and diverse microbial community[5]	cfu/g

3.3 Physicochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC3 category are included in Table 3.4.

Table 3.4 – Physicochemical properties.

#	Parameter	Value	Unit
1	Moisture	Range: 23.7-80.20%; mean: 53.69 % Typically range: 30–55%; mean ≈ 40–45%[3]	%
2	pH	Range: 7.8-903; mean: 8.54 Typically range: 7.0–8.5; mean ≈ 7.8; slightly alkaline[2]	-
3	Electrical conductivity (EC)	Range: 2.7-2.72%; mean: 2.71% Moderate (2–6 mS/cm); depends on feedstock[7]	S/m
4	C/N ratio	Range: 11.42-24; mean: 17.83 Typically range: 10–18; mean ≈ 14; maturity indicator[3]	-
5	Cation Exchange Capacity (CEC)	High; linked to humified organic matter[3]	meq/100 g

3.4 Contaminants and safety indicators

The average values in terms of contaminants for fertilizing products belonging to the CMC3 category are included in Table 3.5. The contaminant values reported are derived from the analytical data and sources available for the CMC3-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 3.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	Range: 0.27-0.90%; mean: 0.53% Typically <1.5 mg/kg DM; within regulatory limits[2]	mg/kg
2	Pb	Range: 17.7-48 %; mean: 29.99% Typically <120 mg/kg DM[2]	mg/kg
3	Cr	Range: 15-38%; mean: 25.05% Typically <100 mg/kg DM[2]	mg/kg
4	Hg	Range: 0.07-0.1%; mean: 0.08% Typically <1 mg/kg DM[2]	mg/kg
5	Ni	Range: 7.1-18.3%; mean: 11.09% Typically <50 mg/kg DM[2]	mg/kg

6	Heavy metal concentration	Generally compliant with EU limits[2]	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	Low after screening (<0.5%); plastics and stones removed[2]	
8	Other contaminants	Not systematically reported; low in controlled systems[3]	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	High stability; respiration index low[3]	
10	Human pathogens	*E. coli:* 283 CFU/g *Salmonella*: not detected Absent after sanitization phase (>55°C)[2]	CFU/g or 25 g
11	Weeds	Absent; thermal destruction of seeds[3]	n° seeds per liter

4 Fertilizing products analysis and characterization – CMC5

Category CMC5 – Digestate → Related products/technologies n° 3, 5, 6, 11, 15, 16, 19, 20.

4.1 Nutrient content

The average values in terms of macronutrients for fertilizing products belonging to the CMC5 category are included in Table 4.1.

Table 4.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	Bibliographic range: 2–8% DM; mean ≈ 5% DM; reduced compared to feedstock due to anaerobic mineralisation[6-7]	%
2	N_{total}	Range: 0.66-10.06% DM; mean ≈2.97 % DM; consistent with livestock and agro-industrial digestates[5-7-8]	%
3	$N_{organic}$	Range: 20–50% of total N; mean ≈ 35%; significantly reduced compared to raw biomass[7]	%
4	N available (NH_4-N, NO_3-N)	NH_4-N → Range: 1.72-2.68% DM; mean ≈ 2.2%; dominant mineral form; NO_3-N → T19: 2.47% negligible[7-8]	%
5	P_{total}	Range: 0.1-2.43% DM; mean ≈0.8 % DM; distribution depends on solid–liquid separation[5-6]	%
6	Available P_2O_5	Range: 0.2–0.51% DM; mean ≈ 0.355% DM; moderate content.	%
7	K_2O	Range: 0.18-6.24% DM; mean ≈2.12 % DM; highly soluble and largely conserved[6]	%
8	CaO	Range: 0.13 % - 2.67 % DM; ; mean ≈ 1.19 % DM[7]	%
9	MgO	Range: 0.04 % - 0.41 % DM; ; mean ≈ 0.22 % DM[6]	%
10	S	Range: 0.05–0.3% FM; mean ≈ 0.15% FM; associated with protein degradation and sulphate formation[7]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC5 category are included in Table 4.2.

Table 4.2 - Micronutrients

#	Parameter	Value	Unit
1	B	Range: 5.7-19 mg/kg DM; mean ≈ 11.9 mg/kg DM Trace levels; typically <10 mg/kg FM; rarely reported analytically[7]	mg/kg
2	Cu	Range: 5.5-200 mg/kg DM; mean ≈ 66.62 mg/kg DM Range: 10–150 mg/kg DM; mean ≈ 60 mg/kg DM, strongly dependent on animal diet and feed additives[5]	mg/kg
3	Fe	Range: 58–4984 mg/kg DM; mean ≈ 1804 mg/kg DM[6]	mg/kg
4	Mn	Range: 59–110 mg/kg DM; mean ≈ 80 mg/kg DM[5]	mg/kg
5	Zn	Range: 28–510 mg/kg DM; mean ≈ 185 mg/kg DM[5]	mg/kg

4.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC5 category are included in Table 4.3.

Table 4.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Present; derived from anaerobic protein degradation; concentrations not consistently quantified; potential biostimulant effect[9,10]	%
2	Humus substances	Low to moderate; significantly lower than compost due to limited humification[7]	%
3	Other stimulants	Presence of soluble organic compounds and low molecular weight organic acids[5]	%
4	Plant growth stimulating microorganisms	Active microbial community present in fresh digestate[7]	cfu/g

4.3 Physicochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC5 category are included in Table 4.4.

Table 4.4 – Physicochemical properties

#	Parameter	Value	Unit
1	Moisture	Range: 55.5-98% FM; mean ≈ 75.25% FM (liquid digestate)[7]	%
2	pH	Range: 5.5–9.09; mean ≈ 7.76; Range: 7.5–8.5; mean ≈ 8.0; slightly alkaline[7]	-
3	Electrical conductivity (EC)	Range: 5–20 S/m; mean ≈ 10–12 S/m; high salinity due to dissolved ions[6]	S/m
4	C/N ratio	Range: 5–10; mean ≈ 7; indicative of strong mineralisation[7]	-
5	Cation Exchange Capacity (CEC)	Moderate; lower than compost[3]	meq/100 g

4.4 Contaminants and safety indicators

The average values in terms of contaminants for fertilizing products belonging to the CMC5 category are included in Table 4.5. The contaminant values reported are derived from the analytical data and sources available for the CMC5-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 4.5 – Contaminants and safety indicators

#	Parameter	Value	Unit
1	Cd	Range: 0.6-0.7; mean ≈ 0.65 Generally low; compliant with EU regulatory limits[2]	mg/kg
2	Pb	Range: 3–17; mean ≈ 10 Low; dependent on feedstock[2]	mg/kg
3	Cr	Range: 13–21; mean ≈ 17 Low–moderate[6]	mg/kg
4	Hg	Range: 0.05–0.5; mean ≈ 0.275 Trace levels; typically very low[2]	mg/kg
5	Ni	Range: 9–18; mean ≈ 13.5 Low–moderate[6]	mg/kg

6	Heavy metal concentration	Generally compliant with EU limits[2]	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	Variable; depends on pre-treatment and feedstock sorting[2]	
8	Other contaminants	Potential presence of organic micropollutants; not systematically reported [11]	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	Digestates are partially stabilised by anaerobic digestion; their final stability depends on process conditions and any subsequent maturation treatment.[7]	
10	Human pathogens	*E. coli:* 73 CFU/g *Salmonella*: not detected Reduced but not always fully eliminated; depends on AD process conditions[2]	CFU/g or 25 g
11	Weeds	Generally absent due to anaerobic digestion conditions[7]	n° seeds per liter

5 Fertilizing products analysis and characterization – CMC10

Category CMC10 – Animal by-products→ Related products/technologies n°

13, 14, 15, 20

5.1 Nutrient content

Table 5.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	Range: 4.63-23.6% FM, Mean: 14.115% FM 30–60% DM typical of protein hydrolysates[10,12,13]	%
2	N_{total}	Range: 1.1-8.86% FM, Mean: 4.95% FM 8–16% DM in protein hydrolysates[12,13]	%
3	$N_{organic}$	Predominantly organic (>90% of total N)[12,13]	%
4	N available (NH_4-N, NO_3-N)	NH_4-N: 0.56% FM Low mineral N; mainly amino-N[10]	%
5	P_{total}	Range: 0.025-2.5% FM, Mean: 0.98% FM, 0.2–1.0% DM depending on raw material[12]	%
6	Available P_2O_5	Range: 0.025-2.01% FM, Mean: 1.02% FM Low–moderate content[12]	%
7	K_2O	Range: 0.096-3.9% FM, Mean: 1.28%FM 0.5–2.0% DM[10,12]	%
8	CaO	Range: 0.2-2.09 % FM Mean: 1.09 %FM Variable depending on processing[10]	%
9	MgO	Range: 0.022-2% FM Mean: 0.58% FM Low content[10]	%
10	S	0.5–3% DM in keratin-derived hydrolysates[14]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC10 category are included in Table 5.2.

Table 5.2 - Micronutrients

#	Parameter	Value	Unit
1	B	Range: 0.2-25 mg/kg Mean: 8.92 mg/kg Trace levels[10]	mg/kg
2	Cu	Range 0.5-3418 mg/kg; mean ≈ 921 mg/kg 5–50 mg/kg DM depending on feedstock[10]	mg/kg
3	Fe	Range: 1-2692 mg/kg; mean ≈ 771 mg/kg 100–1000 mg/kg DM[10]	mg/kg
4	Mn	Range 0.21-8.1 mg/kg; mean ≈ 2.93 mg/kg 10–200 mg/kg DM[10]	mg/kg
5	Zn	Range: 0.5-12860 mg/kg; mean ≈ 3391 mg/kg 20–200 mg/kg DM[10]	mg/kg

5.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC10 category are included in Table 5.3.

Table 5.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Range: 1.5-15% FM; mean ≈ 8.25% FM 20–80% of organic fraction; main active component[12,13]	%
2	Humus substances	3% Low compared to compost[10]	%
3	Other stimulants (specify)	Peptides and phytohormone precursors[10,13]	%
4	Plant growth stimulating microorganisms	Enhanced nutrient uptake, root growth and stress tolerance[12,15]	cfu/g

5.3 Physicochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC10 category are included in Table 5.4.

Table 5.4 – Physicochemical properties

#	Parameter	Value	Unit
1	Moisture	Range: 75-95.%; mean ≈ 87% Variable depending on formulation[10]	%
2	pH	Range: 4.47-8; mean ≈ 6.37 Typically 5–7[10]	-
3	Electrical conductivity (EC)	Range: 4.3-52; mean ≈ 28.15 Moderate salinity[10]	S/m
4	C/N ratio	Low (3–6) due to high N content[12]	-
5	Cation Exchange Capacity (CEC)	Low[10]	meq/100 g

5.4 Contaminants

The average values in terms of contaminants for fertilizing products belonging to the CMC10 category are included in Table 5.5. The contaminant values reported are derived from the analytical data and sources available for the CMC10-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 5.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	Range: 0.03-1.5 mg/kg; mean ≈ 0.605 mg/kg Typically <1 mg/kg DM[2]	mg/kg
2	Pb	Range: 0.81-5.8 mg/kg; mean ≈ 2.77 mg/kg <120 mg/kg DM[2]	mg/kg
3	Cr	Range: 0.4-13 mg/kg; mean ≈ 6.48 mg/kg <100 mg/kg DM[2]	mg/kg
4	Hg	Range: 0.0052-0.5 mg/kg; mean ≈ 0.2526 mg/kg <1 mg/kg DM[2]	mg/kg
5	Ni	Range: 4.4-18 mg/kg; mean ≈ 11.2 mg/kg <50 mg/kg DM[2]	mg/kg

6	Heavy metal concentration	Generally low[2]	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	Negligible (processed materials)	
8	Other contaminants	Possible salts depending on process[10]	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	Not relevant for hydrolysates	
10	Human pathogens	*E. coli:* 0 CFU/g *Salmonella*: not detected Absent after processing[2]	CFU/g or 25 g
11	Weeds	<2 Absent	n° seeds per liter

6 Fertilizing products analysis and characterization – CMC11

Category CMC11 – Industrial by-products → Related products/technologies n° 12

Although technology n°12 is not fully compliant under any CMC due to the use of sewage sludge in the production process, it has been included under CMC 11 because the output aligns with CMC 11 criteria. Consequently the following table are not representative of all materials covered by CMC11, but mainly related to sewage sludge processed with technology n°12.

6.1 Nutrient content

The average values in terms of macronutrients for fertilizing products belonging to the CMC11category are included in Table 6.1.

Table 6.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	10	%
2	N_{total}	Range: 2.13-5% FM, Mean: 3.56% FM No public batch value was found; raw digestate from potato residues is expected to retain relevant total N, with the thick fraction containing part of the total N but less immediately available N than the liquid-rich phase[7,16]	%
3	$N_{organic}$	Not numerically separated; literature indicates hydrolysis liquor may retain a high proportion of organic N, including soluble protein and amino-acid-derived fractions, rather than containing only mineral N[7,16].	%
4	N available (NH_4-N, NO_3-N)	Available N (NH_4^+): not numerically declared; literature indicates hydrolysis-derived sludge liquor contains readily available N, with ammoniacal N expected to dominate over nitrate in freshly produced hydrolysis liquor[7,16]. Available N (NO_3^-): not numerically declared; literature indicates hydrolysis-derived sludge liquor contains readily available N, with ammoniacal N expected to dominate over nitrate in freshly produced hydrolysis liquor[7,16].	%
5	P_{total}	0.22 Not separately declared as elemental P; the product sheet declares P_2O_5 min. 1%	%

		DM; literature supports recovery of P-bearing liquor fractions from sewage-sludge hydrolysis, although product availability depends on process chemistry[7,16].	
6	Available P_2O_5	Range: 0.22-1% FM, Mean: 0.61% FM P_2O_5 min. 1% DM; this supports a fertilizer function, while literature indicates hydrolysis-derived liquor can serve as a liquid fertilizer rich in plant-growth-promoting nutrients[7,16].	%
7	K_2O	Range: 3.67-20% FM, Mean: 11.83% FM K_2O min. 20% DM; this is the most concentrated declared macronutrient in the product sheet and supports a strong fertilizer claim[7,16].	%
8	CaO	0.069 Not declared as CaO, but Ca <0.1% is reported among trace constituents; literature suggests alkaline hydrolysis chemistry strongly affects Ca partitioning, but the dossier does not support a major Ca fertilizer role[7,16].	%
9	MgO	0.035 Not declared as MgO, but Mg <0.1% is reported; this indicates only a minor Mg contribution at product-sheet level.	%
10	S	S min. 5% DM; this supports an additional nutrient function beyond N-P-K and is consistent with concentrated liquid fertilizer positioning[7,16].	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC11 category are included in Table 6.2.

Table 6.2 - Micronutrients

#	Parameter	Value	Unit
1	B	1.4; this indicates trace presence rather than a declared micronutrient claim.	mg/kg
2	Cu	2.1; this supports trace presence only.	mg/kg
3	Fe	131; this supports trace presence only.	mg/kg
4	Mn	0.1; this supports trace presence only.	mg/kg
5	Zn	12	mg/kg

6.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC11 category are included in Table 6.3.

Table 6.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	not declared numerically; literature on alkaline thermal hydrolysis of sewage sludge reports free amino acids up to 56.82 g/L in hydrolysis liquor under optimized conditions, supporting the plausibility of amino-acid-rich soluble fractions in hydrolysed sludge products.	%
2	Humus substances	present in the questionnaire and humic acid min. 1% DM in the product sheet; literature confirms that sewage sludge contains significant humic substances and that treatment can increase recoverable humic-substance concentration.	%
3	Other stimulants	fulvic acid is present; literature shows hydrolysis liquor can also contain phytohormone-like compounds and other nitrogen-containing plant-growth-promoting biostimulants.	%
4	Plant growth stimulating microorganisms	not declared; because the marketed product is a liquid concentrate obtained after strong chemical processing and low-pH stabilisation, the dossier supports a chemical/organic biostimulant interpretation rather than a microbial biostimulant claim.	cfu/g

6.3 Physiochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC11 category are included in Table 6.4.

Table 6.4 – Physicochemical properties

#	Parameter	Value	Unit
1	Moisture	27; described as liquid fertilizer / colloidal liquid; no exact moisture percentage is given, but the product is clearly positioned as a liquid concentrate.	%
2	pH	3.5 in the questionnaire and 3 in the nutrient solution sheet; this consistently indicates a strongly acidic liquid product.	-
3	Electrical conductivity (EC)	n/a; no product value is provided.	S/m
4	C/N ratio	0.95	-
5	Cation Exchange Capacity (CEC)	n/a; however, the product sheet explicitly claims improved soil cation exchange capacity after use, consistent with humic/fulvic action rather than a measured product CEC.	meq/100 g

6.4 Contaminants

The average values in terms of contaminants for fertilizing products belonging to the CMC11 category are included in Table 6.5. The contaminant values reported are derived from the analytical data and sources available for the CMC11-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 6.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	0.03; max 2 mg/kg as questionnaire specification; this is presented as a product limit, not a measured batch value.	mg/kg
2	Pb	0.77	mg/kg
3	Cr	37	mg/kg
4	Hg	max 1; specification/limit only.	mg/kg

5	Ni	25	mg/kg
6	Heavy metal concentration	questionnaire reports heavy metal concentration max 10 and separate maxima for Cd, Pb, Cr, Hg, Ni; these are specifications, not measured batch concentrations.	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	0 for impurities and 0 for >2 mm glass/metals/plastics and >5 mm stones in the questionnaire.	
8	Other contaminants	PAH, TPH identified as relevant contaminants to control; no measured batch values are reported in the available dossier.	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	not reported; for this product family, stability is less relevant than for compost because the marketed material is a hydrolysed liquid concentrate rather than a solid organic amendment.	
10	Human pathogens	Max 10 CFU/25g	CFU/g or 25 g
11	Weeds	Not applicable	n° seeds per liter

7 Fertilizing products analysis and characterization – CMC12

Category CMC12 – Precipitated phosphate salts & derivates → Related products/technologies n° 17, 18,19

7.1 Nutrient content

Table 7.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	~0%; mineral fertilizer, negligible organic carbon[17,18,19,20,21,22,23,24]	%
2	N_{total}	Range: 4.43-5.7% DM; mean ≈ 5.17% DM 5–7% DM; present as NH_4^+ in struvite structure[17,18,19,20,21,22,23,24]	%
3	$N_{organic}$	0%; purely mineral N[17]	%
4	N available (NH_4-N, NO_3-N)	NH_4-N Range: 5.02-5.7% FM; mean ≈ 5.36% FM NO_3-N: 0.237% FM 100% of total N; slow-release due to low solubility[18,19]	%
5	P_{total}	Range: 25.81–32.78%; mean 29.29% high P concentration[17,18,19,20,21,22,23,24]	%
6	Available P_2O_5	Range: 18.92-28.9%; mean 24.14% FM; Moderate content; release controlled by soil pH (higher in acidic soils)[19-22]	%
7	K_2O	Range: 0.061-2.95, mean 1.50 %FM not present in struvite[17,18,19,20,21,22,23,24]	%
8	CaO	Range: 0.26-0.49, mean 0.375 %FM Trace–low; depends on impurities[12]	%
9	MgO	Range: 10.5-16, mean 12.84 %FM 9–10% Mg (≈15–16% MgO); intrinsic component[17-18]	%
10	S	Not present unless co-precipitated[12]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC12 category are included in Table 7.2.

Table 7.2 - Micronutrients

#	Parameter	Value	Unit
1	B	1 DM Not significant; typically absent[17]	mg/kg
2	Cu	Range: 2-15, mean 8.5 DM depends on wastewater origin[22,25]	mg/kg
3	Fe	Range: 109-735, mean 422 DM may co-precipitate[12]	mg/kg
4	Mn	0.1 DM trace levels[22]	mg/kg
5	Zn	Range: 8.1-3823, mean 1915 % DM depends on feedstock contamination[25]	mg/kg

7.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC12 category are included in Table 7.3.

Table 7.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Not present; mineral product[17]	%
2	Humus substances	Not present[17]	%
3	Other stimulants	None; agronomic effect is nutrient-based[18]	%
4	Plant growth stimulating microorganisms	Not present; precipitation process eliminates biological activity[12]	cfu/g

7.3 Physicochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC12 category are included in Table 7.4.

Table 7.4 – Physicochemical properties

#	Parameter	Value	Unit
1	Moisture	<5–10%; dry crystalline product[18]	%
2	pH	8.5-8.93; slightly alkaline[17]	-
3	Electrical conductivity (EC)	Low–moderate[12]	S/m
4	C/N ratio	Not applicable (mineral fertilizer)	-
5	Cation Exchange Capacity (CEC)	Not applicable	meq/100 g

7.4 Contaminants

The average values in terms of contaminants for fertilizing products belonging to the CMC12 category are included in Table 7.5. The contaminant values reported are derived from the analytical data and sources available for the CMC12-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 7.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	0.27 DM; generally low[2,25]	mg/kg
2	Pb	0.44 mg/kg DM[2]	mg/kg
3	Cr	Range: 4.8-6.1, mean 5.45 mg/kg DM[25]	mg/kg
4	Hg	<0.1–0.5 mg/kg DM [2]	mg/kg
5	Ni	Range: 1.2-4.5, mean 5.45 mg/kg DM[25]	mg/kg
6	Heavy metal concentration	Generally low[2]	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	Low; high purity crystalline product[17]	
8	Other contaminants	Possible PFAS/microplastics traces depending on source[17,22,25,26,27]	

9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	Not applicable	
10	Human pathogens	Absent due to crystallisation conditions[12]	CFU/g or 25 g
11	Weeds	Not applicable	n° seeds per liter

8 Fertilizing products analysis and characterization – CMC14

Category CMC14 – Pyrolysis and gasification materials → Related products/technologies n° 23, 24, 25

8.1 Nutrient content

The average values in terms of macronutrients for fertilizing products belonging to the CMC14 category are included in Table 8.1.

Table 8.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	60–90% DM highly carbonised structure depending on pyrolysis temperature[14,28,29,14,30,31]	%
2	N_{total}	0.2 DM 0.3–2.0% DM low due to volatilisation during pyrolysis[14,28,30,31,32]	%
3	$N_{organic}$	Present but recalcitrant; largely unavailable short-term[14,29,30,31]	%
4	N available (NH_4-N, NO_3-N)	Negligible; biochar is not a direct N fertilizer[14,30,31,33]	%
5	P_{total}	0.11 DM 0.1–1.5% DM varies with feedstock ash content[14,28,30,31]	%
6	Available P_2O_5	0.12 DM Low–moderate content depending on ash and pH[14,30,31, 33]	%
7	K_2O	0.15 DM 0.5–5.0% DM often elevated due to ash concentration[14,28,29,30,31]	%
8	CaO	2.8 DM 1–10% DM contributes to liming effect[29]	%
9	MgO	0.14 DM 0.2–2.0% DM secondary nutrient contribution[28]	%
10	S	0.05–0.5% DM partially lost during pyrolysis[28]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC14 category are included in Table 8.2.

Table 8.2 - Micronutrients

#	Parameter	Value	Unit
1	B	13 DM 10–100 mg/kg DM depends on feedstock[28]	mg/kg
2	Cu	8.4 DM 10–200 mg/kg DM concentrated in ash fraction[29]	mg/kg
3	Fe	1734 DM 1000–50000 mg/kg DM highly variable depending on biomass origin[28]	mg/kg
4	Mn	0.42 DM 50–2000 mg/kg DM typical plant-derived range[29]	mg/kg
5	Zn	28 DM 20–500 mg/kg DM influenced by feedstock contamination[28]	mg/kg

8.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC14 category are included in Table 8.3.

Table 8.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Not present; destroyed during pyrolysis[9,10,12,13,15,29,30]	%
2	Humus substances	Not humic, but contains stable aromatic carbon structures[9,10,12,13,15,29,30,34]	%
3	Other stimulants	Indirect effects via adsorption, microbial habitat, and nutrient retention[9,10,12,13,15,29,30,34]	%
4	Plant growth stimulating microorganisms	Not present in product, but promotes microbial colonisation in soil[34]	cfu/g

8.3 Physiochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC14 category are included in Table 8.4.

Table 8.4 – Physiochemical properties

#	Parameter	Value	Unit
1	Moisture	38% typically low due to thermal treatment[28]	%
2	pH	8.58 7–10 alkaline due to ash content[29]	-
3	Electrical conductivity (EC)	850 S/m Variable; increases with ash content[28]	S/m
4	C/N ratio	50–500 extremely high due to carbonisation[32]	-
5	Cation Exchange Capacity (CEC)	10–200 meq/100g; increases with ageing[34]	meq/100 g

8.4 Contaminants

The average values in terms of contaminants for fertilizing products belonging to the CMC14 category are included in Table 8.5. The contaminant values reported are derived from the analytical data and sources available for the CMC14-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 8.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	0.21 DM <1–5 mg/kg DM depends on feedstock[2,28]	mg/kg
2	Pb	7.3 DM <10–100 mg/kg DM variable[2]	mg/kg
3	Cr	36 DM <10–100 mg/kg DM[28]	mg/kg
4	Hg	<0.1–1 mg/kg DM generally very low[2]	mg/kg
5	Ni	<10–100 mg/kg DM[28]	mg/kg
6	Heavy metal concentration	Generally compliant if clean biomass used[2,14,31,35,14]	
7	Impurities (glass, metals,	Low if controlled feedstock used[14,29,31,35]	

	plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones		
8	Other contaminants	Possible PAHs depending on process conditions[28]	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	Not applicable (thermochemically stabilised)	
10	Human pathogens	*E. coli:* 0 CFU/g *Salmonella*: not detected Absents due to high temperature treatment[29]	CFU/g or 25 g
11	Weeds	Absent (thermal destruction of seeds)	n° seeds per liter

9 Fertilizing products analysis and characterization – CMC15

Category CMC15 – Recovered high purity materials→ Related products/technologies n° 4, 19, 20, 21, 22.

9.1 Nutrient content

The average values in terms of macronutrients for fertilizing products belonging to the CMC15 category are included in Table 9.1. The reported values refer to product types comparable to those associated with the selected FERTICOVERY technologies and should not be interpreted as representative of all materials potentially covered by CMC15.

Table 9.1 - Macronutrients

#	Parameter	Value	Unit
1	$C_{organic}$	~0%; mineral fertilizers[12,36,37,38,39]	%
2	N_{total}	Range: 4.43-5.7FM Mean: 5.17FM 5–12% N (liquid); 20–21% N (ammonium sulphate dry equivalent)[12,36,37,38,39,40]	%
3	$N_{organic}$	0%; nitrogen entirely mineral (NH_4^+)[12]	%
4	N available (NH_4-N, NO_3-N)	NH_4-N Range: 6-12 FM; mean ≈ 8.975 FM NO_3-N: 9 FM N available ≈ 100% of total N; immediately plant-available[8,40]	%
5	P_{total}	Range: 25.81-32,70 Mean: 29.29 %	%
6	Available P_2O_5	Range: 18.92-28.9% Mean: 21.14%	%
7	K_2O	Range: 0.061-2.95FM Mean: 1.50FM negligible[12,36,37,38,39]	%
8	CaO	Range: 0.26 – 0.49 FM Mean: 0.375 FM	%
9	MgO	Range: 10.5-16 FM Mean: 12.84FM	%
10	S	24% S (ammonium sulphate equivalent); relevant secondary nutrient[16]	%

The average values in terms of micronutrients for fertilizing products belonging to the CMC15 category are included in Table 9.2.

Table 9.2 - Micronutrients

#	Parameter	Value	Unit
1	B	1[16]	mg/kg
2	Cu	Range: 2-15 DM Mean: 8.5 DM Often <1–10 mg/kg; very low due to purification[40]	mg/L
3	Fe	Range: 109-735 DM Mean: 422 DM	mg/kg
4	Mn	Ammonium sulphate/nitrate mix: 16mg/L <1–10 mg/kg	mg/kg
5	Zn	Ammonium sulphate/nitrate mix: 3.4mg/L <1–10 mg/kg; trace impurities only[40]	mg/kg

9.2 Plant stimulants

The average values in terms of plant stimulants for fertilizing products belonging to the CMC15 category are included in Table 9.3.

Table 9.3 – Plant stimulants

#	Parameter	Value	Unit
1	Amino acids	Not present; mineral product[16]	%
2	Humus substances	Not present	%
3	Other stimulants	None; purely nutrient-based effect[8]	%
4	Plant growth stimulating microorganisms	Not present; chemically produced fertilizer	cfu/g

9.3 Physicochemical properties

The average values in terms of available physicochemical properties for fertilizing products belonging to the CMC15 category are included in Table 9.4.

Table 9.4 – Physicochemical properties

#	Parameter	Value	Unit
1	Moisture	Range: 56.3-58.9% Mean: 57.6% Liquid products typically 85–95% water; solid salts <5%[40]	%
2	pH	5.5-8.5 5–7 (ammonium sulphate solutions)[16]	-
3	Electrical conductivity (EC)	2 mS/cm High; due to soluble salts[12]	S/m
4	C/N ratio	Not applicable	-
5	Cation Exchange Capacity (CEC)	Not applicable	meq/100 g

9.4 Contaminants

The average values in terms of contaminants for fertilizing products belonging to the CMC15 category are included in Table 9.4. The contaminant values reported are derived from the analytical data and sources available for the CMC15-related product types considered in this deliverable. They should not be interpreted as measured or statistically representative contaminant levels across the EU, as contaminant occurrence may vary considerably depending on feedstock origin, geographical context and process conditions.

Table 9.5 – Contaminants

#	Parameter	Value	Unit
1	Cd	Range: 0.03-0.27 DM Mean: 0.15 DM <0.1–1 mg/kg; very low[2]	mg/kg
2	Pb	Range0.25-0.44 DM Mean: 0.345 DM	mg/kg
3	Cr	Range: 4.8-6.1 DM Mean: 5.45 DM	mg/kg
4	Hg	<0.01–0.1 mg/kg	mg/kg
5	Ni	Range: 1.2-4.5 DM Mean: 2.85 DM <1–10 mg/kg[40]	mg/kg
6	Heavy metal concentration	Generally low in the product types considered; contaminant concentrations depend on the feedstock and the specific	

		recovery and purification process.[2,40]	
7	Impurities (glass, metals, plastics, etc.), specific size: >2 mm for glass, metal and plastics; >5 mm for stones	Low; high purity recovered product[16]	
8	Other contaminants	Very low; process removes organic contaminants[12]	
9	Stability and maturity indicators (e.g. germination index, oxygen uptake rate, rotting degree, residual biogas potential) – from EU Fertilising Regulation	Not applicable	
10	Human pathogens	*E. coli:* 0 CFU/g *Salmonella*: not detected Absents due to chemical process[40]	CFU/g or 25 g
11	Weeds	Not applicable	n° seeds per liter

10 Fertilizing products compliance with EU 1009/2019

The compliance assessment table provides a structured overview of how the fertilizing products derived from the analysed technologies align with the requirements of **EU Regulation 2019/1009 on fertilising products**. The table is designed to support a comparative and transparent evaluation of regulatory readiness across different categories of recovered fertilising products.

The assessment is carried out at **category level**, rather than for individual technologies, in order to reflect the intrinsic variability of products derived from similar processes (e.g. composting, digestate treatment, crystallisation, pyrolysis). This approach allows for a more robust interpretation of compliance, especially in cases where product composition is strongly dependent on feedstock and process conditions.

Each entry in the table includes the following elements:

- **Technology ID**: anonymised identifier assigned to each technology to ensure neutrality and comparability.
- **Category**: grouping of technologies based on the type of fertilizing product (e.g. compost-based, digestate-based, struvite-based, ammonium salts, biochar).
- **PFC (Product Function Category)**: classification according to the intended function of the product under EU Regulation 2019/1009 (e.g. PFC1 fertilising product, PFC3 soil improver, PFC6 biostimulant).
- **CMC (Component Material Category)**: classification of input materials and processing routes, indicating whether the product is eligible under specific categories such as compost (CMC3), digestate (CMC5), precipitated phosphate salts (CMC12), or pyrolysis materials (CMC14 – STRUBIAS).
- **Nutrient availability**: qualitative indication of the relevance of the product as a nutrient source (e.g. high nitrogen, high phosphorus, low nutrient content).
- **EU Compliance**: qualitative assessment of regulatory alignment, expressed as:
    - *Compliant*: available data indicate that the product can meet the main requirements of the regulation, including nutrient declaration, contaminant limits, and hygienisation (where applicable).
    - *Potentially compliant*: compliance is conditional and may vary depending on specific process parameters, feedstock quality, or additional treatment steps required to meet regulatory thresholds. Missing or insufficient information that may affect the ability to fully demonstrate compliance (e.g. lack of contaminant data, absence of microbiological analysis, incomplete nutrient characterization).

It is important to note that this compliance assessment is **indicative and not a formal conformity evaluation**. Full compliance with EU Regulation 2019/1009 requires:

- certified analytical data,
- conformity assessment procedures,
- and CE marking in accordance with the applicable PFC and CMC requirements.

The table therefore serves as a **screening tool** to:

- identify technologies with high regulatory readiness,
- highlight critical data gaps that may hinder market entry,
- and support further technical, regulatory, and economic evaluations within the project.

In particular, the analysis confirms that:

- well-established products such as compost and struvite generally show a **high level of compliance readiness**, supported by existing standards and analytical datasets;
- mineral fertilising products recovered from waste streams (e.g. ammonium salts) are typically **compliant**, provided purity and concentration requirements are met;
- emerging products such as biochar and advanced nutrient concentrates may require **additional validation**, especially regarding contaminant levels, agronomic efficiency, and classification under STRUBIAS-related CMCs.

Overall, the compliance table provides a **transparent bridge between technological development and regulatory applicability**, enabling a better understanding of how nutrient recovery solutions can be integrated into the European fertilising product market.

Table 10.1 – Integrated Assessment of Fertilizing Products and Compliance with EU Regulation 2019/1009

Technology ID #	Category	PFC	CMC	Nutrients Availability	EU Compliance	Reason	Data Gaps
1	Compost	PFC3(A)	CMC3	Medium	Compliant	The product is obtained from source-separated bio-waste through anaerobic digestion followed by aerobic composting, which is consistent with CMC 3 requirements. Reported heavy metals, physical impurities and hygienic parameters are compatible with Regulation (EU) 2019/1009.	Confirmation of compliance with all CMC 3 contaminant requirements (e.g. PAHs where applicable) and validated stability/maturity parameters required by the Regulation.
2	Compost, digestate	PFC3(A)	CMC3	Medium	Compliant	The production	Confirmation of all

						process (thermophilic anaerobic digestion followed by composting) is consistent with CMC 3. Available contaminant and microbiological data do not indicate compliance issues.	contaminant parameters required by CMC 3 and validated maturity/stability indicators.
3	Compost	PFC3(A)	CMC5	Medium	Compliant	The product corresponds to CMC 5 digestate. No evidence of non-compliance is identified from the available contaminant and hygienisation data.	Analytical values for all regulated heavy metals (Cd, Pb, Hg, Cr, Ni) should be provided instead of generic statements, together with confirmation that only eligible input materials were used.
4	Digestate (solid and liquid fraction), Liquid ammonium sulphate/nitrate, Potassium salts	PFC1(C)-3(A)	CMC5, CMC15	High N	Compliant	The recovered ammonium salts are consistent with CMC 15 recovered high-purity materials. Reported contaminant levels are very low and compatible with the Regulation.	Evidence demonstrating fulfilment of CMC 15 purity criteria and process-specific requirements for recovered high-purity materials.
5	Digestate (solid and liquid fraction)	PFC1(A)-3(A)	CMC5	High N	Potentially compliant	The production process is compatible with CMC 5, but compliance cannot be fully assessed	Product-specific analytical data for regulated heavy metals, microbiological criteria, physical impurities and

						because most contaminant data are missing or based on literature values rather than product-specific analyses.	confirmation of eligible feedstocks.
6	Digestate (solid and liquid fraction)	PFC3	CMC5	High N	Potentially compliant	The production process is consistent with CMC 5 requirements for digestate derived from food waste and organic residues. However, compliance cannot be fully assessed because contaminant data are mainly based on literature values rather than product-specific analyses.	Product-specific analytical data for regulated heavy metals, microbiological criteria, physical impurities, and confirmation that only eligible input materials were used.
7	Compost	PFC3(A)	CMC3	Medium	Compliant	The compost is produced from source-separated bio-waste through controlled aerobic composting. Reported heavy metals, physical impurities and hygienic parameters are compatible with Regulation (EU) 2019/1009.	Confirmation of regulated organic contaminants (where applicable) and validated maturity/stability indicators according to CMC 3 requirements.
8	Compost	PFC3(A)	CMC3	Medium	Compliant	The product is obtained	Confirmation of regulated

						exclusively from green waste through aerobic composting and is consistent with CMC 3. Available contaminant, impurity and microbiological data indicate no compliance concerns.	organic contaminants (where applicable).
9	Compost	PFC3(A)	CMC3	Medium	Compliant	The composting process and reported contaminant profile are consistent with CMC 3 requirements. Heavy metals, impurities and hygienic parameters are compatible with Regulation (EU) 2019/1009.	Confirmation of regulated organic contaminants (where applicable) and validated maturity/stability parameters.
10	Compost	PFC3(A)	CMC3	Medium	Compliant	The product is obtained from 100% garden and park waste through controlled aerobic composting and is certified under RAL-GZ 251. Reported contaminant levels and physical impurities are compatible with Regulation (EU) 2019/1009.	Confirmation of compliance with regulated organic contaminants (where applicable) and microbiological criteria, which are not reported analytically.

11	Digestate (solid fraction)	PFC1(A)	CMC5	High N	Potentially compliant	The production process is consistent with CMC 5. However, compliance cannot be fully demonstrated because product-specific contaminant and hygienisation data are not available.	Feedstock appears compatible with CMC 5, but the eligibility of all input materials is not fully documented. The process itself is technically compatible, but additional evidence is needed to demonstrate that all regulatory processing requirements of the assigned CMC are fulfilled (e.g. process conditions, end-point requirements, purity, validation). Product-specific heavy metals, microbiological criteria and physical impurities.
12	Biostimulants, Liquid organo-mineral fertilizers	PFC1(A)	CMC11	Low N	Not compliant	The production process is not consistent with CMC 11 due to the use of sewage sludge. The fertilizing product can be compliant.	The process itself is technically compatible, but additional evidence is needed to demonstrate that all regulatory processing requirements of the assigned CMC are fulfilled (e.g. process conditions,

							end-point requirements, purity, validation). Batch-specific heavy metals and relevant organic contaminants (where applicable).
13	Mineral concentrat, Liquid organo-mineral fertilizers	PFC1(A)	CMC10	High N	Not compliant	The product is obtained from municipal sewage sludge. This feedstock is not eligible under CMC 10 of Regulation (EU) 2019/1009, which only covers specified animal by-products and derived products. Therefore, the proposed CMC assignment is not applicable.	Feedstock does not meet CMC 10 requirements. Hydrolysis of municipal sewage sludge does not correspond to any recognised transformation route leading to a material covered by the assigned CMC under Regulation (EU) 2019/1009.
14	Liquid organo-mineral fertilizers	PFC1(B)	CMC10	Low N	Potentially compliant	The feedstock (poultry feathers) and hydrolysis process are consistent with CMC 10. Reported contaminant and microbiological data do not indicate compliance issues.	Poultry feathers are potentially eligible under CMC 10, but full compliance also requires demonstration that all Animal By-Product (ABP) requirements and the applicable end-point criteria have been fulfilled.

15	Liquid organo-mineral fertilizers	PFC1(B)	CMC5, CMC10	High	Potentially compliant	The production process is compatible with the assigned CMC. However, analytical evidence for all regulated contaminants is not complete for the final product.	The available analytical dataset is incomplete for the final product.
16	Nitrogen enriched slurry	PFC1(B)	CMC5	High	Potentially compliant	The nitrogen-enrichment process is compatible with the assigned CMC. However, compliance cannot be fully demonstrated because contaminant and microbiological data are incomplete.	Product-specific contaminant and microbiological data are incomplete.
17	Struvite	PFC1(C)	CMC12	High P	Compliant	The feedstock, recovery process and reported contaminant profile are consistent with CMC 12 requirements.	No major compliance data gaps identified.
18	Struvite	PFC1(B)	CMC12	High P	Compliant	The recovered struvite is produced through a controlled crystallisation process consistent with CMC 12. Reported heavy metals, microbiological quality and	No major compliance data gaps identified.

						physical purity do not indicate compliance issues.	
19	Digestate (solid and liquid fraction), Mineral concentrate	PFC3(A)-6	CMC5, CMC15	Variable	Partially compliant	The nutrient recovery process is consistent with CMC 15. However, the feedstock includes industrial WWTP sludge, and analytical data for the final recovered products are incomplete, preventing full assessment of contaminant compliance.	The nutrient recovery process is technically recognised, but because it involves industrial WWTP sludge, compliance depends on whether the recovered products meet the requirements of the applicable CMC (e.g. CMC 15). The process alone cannot be considered automatically compliant. Includes industrial WWTP sludge, which may not always be eligible depending on the recovery route. Product-specific heavy metals, microbiological criteria for the final products and relevant organic contaminants.
20	Liquid digestate, biostimulant	PFC6	CMC10,CMC15	Low	Potentially compliant	The amino acid concentrate is obtained through an eligible	The process itself is technically compatible, but additional evidence is

						recovery process and reported contaminant concentrations, microbiological quality and absence of relevant organic pollutants are compatible with Regulation (EU) 2019/1009.	needed to demonstrate that all regulatory processing requirements of the assigned CMC are fulfilled (e.g. process conditions, end-point requirements, purity, validation). Eligibility depends on the recovered amino-acid production route and compliance with the assigned CMC(s).
21	Liquid ammonium nitrate/sulphate	PFC1(C)	CMC15	High N	Compliant	The ammonia stripping and acid scrubbing process is consistent with CMC 15. Reported contaminant concentrations, microbiological quality and product purity indicate compliance with the Regulation.	No major compliance data gaps identified.
22	Liquid ammonium nitrate/sulphate	PFC1(A)	CMC15	High N	Potentially compliant	The production process is consistent with CMC 15. However, only a limited analytical dataset is available for regulated contaminants, preventing complete	Product-specific analytical data for Hg and other regulated contaminants not reported.

						verification of compliance.	
23	Biochar	PFC3(A)	CMC14	Low nutrients	Compliant	The biochar is produced from clean woody biomass by controlled thermochemical conversion. Available information indicates compliance with contaminant and hygienisation requirements and no incompatibility with CMC 14.	No major compliance data gaps identified.
24	Biochar	PFC3(A)	CMC14	Low nutrients	Compliant	The biochar is produced through controlled pyrolysis of lignocellulosic biomass, consistent with CMC 14. Reported contaminant profile and hygienisation are compatible with Regulation (EU) 2019/1009.	No major compliance data gaps identified.
25	Biochar	PFC3(A)	CMC14	Medium	Potentially compliant	The feedstock and production process are consistent with CMC 14: the product is obtained from green waste through controlled thermochemical carbonisation	Product-specific heavy metals, PAHs/dioxins and physical impurities.

						at high temperature. However, compliance cannot be fully demonstrated because product-specific analytical values for regulated contaminants are not reported.	

11 Conclusions

This deliverable presents a structured assessment of fertilizing products derived from 25 nutrient recovery technologies, covering a wide range of materials including organic fertilising products, mineral fertilising products, organo-mineral products, biostimulants, and soil improvers. The analysis confirms that nutrient recovery processes can generate products with significant agronomic value, capable of contributing to a more circular and sustainable nutrient management system.

Recovered fertilising products show diverse characteristics depending on the technology and feedstock. Products such as struvite and ammonium salts provide concentrated and readily available nutrients comparable to conventional mineral fertilising products, while compost and digestate-based products contribute to soil organic matter and long-term soil fertility. Carbon-based materials, such as biochar, play a complementary role by improving soil structure, water retention, and nutrient efficiency, while also contributing to carbon sequestration.

The comparison with EU Regulation 2019/1009 indicates that several product categories, particularly compost, struvite, and ammonium-based fertilising products, are generally aligned with regulatory requirements when appropriate process control and quality assurance are applied. Other product types, especially those based on emerging technologies or complex mixtures, show a level of compliance that depends on process conditions, product standardisation, and the demonstration of agronomic performance.

Overall, the results highlight the strong potential of nutrient recovery technologies to support the transition towards sustainable fertilization systems. At the same time, they underline the importance of consistent product characterization and clear regulatory positioning to enable wider market uptake. This deliverable provides a coherent framework for understanding these technologies and supports further evaluation of their technical, environmental, and regulatory performance within the project.

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