## Supplementary Material

## S1. Stabilisation process mix

*S1.2. Central region*

There are different types of stabilisation methods. Information on the uptake of the different methods was gathered, when available, for the EU-27 countries [1].

For the central region it was possible to obtain information for some of the stabilisation methods for some countries from literature [1–3]. Regarding composting, in most Member State's reports, it is reported as a sludge disposal method not as a stabilisation method. However, for the purpose of this study these statistics were used. Table S1 details the information found by countries. No information was found for Belgium, Rumania, and the Netherlands.

**Table S1.** Stabilisation method distribution for the central region for sludge

| | **Anaerobic digestion** | **Thermal drying** | **Aerobic digestion** | **Chemical treatment** | **Composting** |
|---|---|---|---|---|---|
| Bulgaria | nda[5] | nda[1] | nda1 | nda1 | 42%[6] |
| Germany | nda[1] | nda[1] | nda[1] | nda[1] | 8%[2] |
| Croatia | nda[1] | nda[1] | nda[1] | nda[1] | 26%[2] |
| Luxemburg | 89% | 0% | 0% | 0% | 11%[2] |
| Hungary | 19% | 0% | 0% | 0% | 81%[2] |
| Austria | nda[1] | nda[1] | nda[1] | nda[1] | 18%[2] |
| Poland | nda[1] | 0% | nda[1] | nda[1] | 4%[2] |
| Slovenia | nda[1] | nda[1] | nda[1] | nda[1] | 4.6%[2] |
| Slovakia | 57% | 0% | 34% | 4.5% | 4.5% |
| **Central region** | **39.4%** | **5.3%** | **34%** | **5.3%** | **15.9%** |

*S1.2. Mediterranean region*

For this region, it was possible to obtain sludge production data for all countries, but not for the same time series. In this sense, for Greece, Malta and Cyprus data was available for 2021, while for Spain, France, Portugal, and Italy data was available for 2018, 2017, 2016 and 2010, respectively. The data of the sludge production per country was collected from Eurostat database [1]

As mentioned before, there are different types of stabilisation methods. The distribution of their utilisation varies from country to country. For the Mediterranean region, it was possible to obtain information from literature [4] only for Spain and only for anaerobic and aerobic digestion. For the rest of the stabilisation methods, an estimation was made assigning the remaining percentage (once the two types of digestion were subtracted) equally among the 3 processes left. Table S2 shows the distribution of the methods.

**Table S2.** Stabilisation method distribution for the Mediterranean region for sludge

| | **Anaerobic digestion** | **Thermal drying** | **Aerobic digestion** | **Chemical treatment** | **Composting** |
|---|---|---|---|---|---|
| Spain | 68.2% | nda% | 13.7% | nda | nda |
| **Mediterranean region** | **68.2%** | **6%** | **13.7%** | **6%** | **6%** |

*S1.3. Northern region*

For the northern region, it was possible to obtain sludge production data for all countries, but not for the same time series. In this sense, for Estonia, Ireland, Latvia, Lithuania, Sweden and Norway data was available for 2021, while for Finland and Denmark data was available for 2020 and 2010, respectively. The data of the sludge production per country was collected from Eurostat database [1].

For the northern region it was possible to obtain information from literature [5] and only for Ireland. Table S3 shows the distribution of the methods. The process mix of Ireland was applied for the entire northern region.

**Table S3.** Stabilisation method distribution for the Mediterranean region for sludge

| | **Anaerobic digestion** | **Thermal drying** | **Aerobic digestion** | **Chemical treatment** | **Composting** |
|---|---|---|---|---|---|
| Ireland | 10.80% | 39.70% | 1.80% | 36.10% | 11.60% |
| **Northern region** | **10.80%** | **39.70%** | **1.80%** | **36.10%** | **11.60%** |

## S2. Environmental performance

**Table S4.** Characterisation results of circular fertiliser for each European region per FU.

| Impact category | Region | Anaerobic digestion | Chemical treatment | Thermal drying | Composting |
|---|---|---|---|---|---|
| **Acidification** | Central | 1,25E-01 | 1,94E-02 | 2,11E-02 | 8,66E-02 |
| | Mediterranean | -7,04E-02 | 1,79E-02 | 1,93E-02 | 2,40E-02 |
| | Northern | 4,03E-03 | 5,84E-02 | 8,43E-02 | 2,71E-02 |
| **Climate change** | Central | 3,80E+01 | 1,27E+01 | 4,84E+00 | 1,79E+01 |
| | Mediterranean | 1,82E+00 | 1,30E+01 | 4,32E+00 | 4,49E+00 |
| | Northern | 2,39E+00 | 5,23E+01 | 1,92E+01 | 5,07E+00 |
| **Eutrophication, marine** | Central | 1,08E-01 | 1,17E-02 | 1,11E-02 | 3,14E-02 |
| | Mediterranean | 1,28E-01 | 1,20E-02 | 1,11E-02 | 9,81E-03 |
| | Northern | 1,62E-02 | 4,61E-02 | 5,19E-02 | 1,26E-02 |
| **Eutrophication, freshwater** | Central | 1,27E-02 | 2,64E-03 | 2,47E-03 | 1,57E-02 |
| | Mediterranean | -1,33E-02 | 1,07E-03 | 1,01E-03 | 1,35E-03 |
| | Northern | -3,58E-04 | 3,61E-03 | 4,06E-03 | 1,29E-03 |
| **Photochemical ozone formation** | Central | 1,44E-01 | 2,31E-02 | 3,29E-02 | 2,33E-02 |
| | Mediterranean | 6,22E-02 | 2,46E-02 | 3,42E-02 | 6,91E-03 |
| | Northern | 1,46E-02 | 8,56E-02 | 1,56E-01 | 5,77E-03 |
| **Resource use, fossils** | Central | 1,21E+02 | 7,53E+01 | 2,26E+02 | 1,85E+02 |
| | Mediterranean | -1,75E+03 | 8,45E+01 | 2,41E+02 | 7,36E+01 |
| | Northern | -1,34E+02 | 2,99E+02 | 1,10E+03 | 7,01E+01 |
| **Resource use, minerals and metals** | Central | 1,55E-05 | 5,45E-06 | 4,81E-06 | 1,88E-05 |
| | Mediterranean | -1,26E-04 | 5,75E-06 | 4,69E-06 | 6,43E-06 |
| | Northern | -1,53E-05 | 2,18E-05 | 2,41E-05 | 9,35E-06 |
| **Water use** | Central | -1,66E+02 | -1,93E+01 | -1,92E+01 | -5,64E+01 |
| | Mediterranean | -3,06E+02 | -2,05E+01 | -2,05E+01 | -2,01E+01 |
| | Northern | -3,30E+01 | -8,93E+01 | -9,73E+01 | -2,81E+01 |

**Table S5.** Normalisation of characterization results of circular and non-renewable fertiliser (NRF) for each European region per FU.

| Impact category | Region | Anaerobic digestion | Chemical treatment | Thermal drying | Composting | NRF |
|---|---|---|---|---|---|---|
| **Acidification** | Central | 5,1 | 0,8 | 0,9 | 3,5 | - |
| | Mediterranean | 0,0 | -0,1 | -0,1 | -0,1 | - |
| | Northern | 0,2 | 2,4 | 3,4 | 1,1 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Climate change** | Central | 14,5 | 4,8 | 1,8 | 6,8 | - |
| | Mediterranean | 0,7 | 5,0 | 1,7 | 1,7 | - |
| | Northern | 0,9 | 20,0 | 7,3 | 1,9 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Eutrophication, marine** | Central | 44,2 | 4,8 | 4,5 | 12,8 | - |
| | Mediterranean | 52,5 | 4,9 | 4,5 | 4,0 | - |
| | Northern | 6,6 | 18,9 | 21,2 | 5,1 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Eutrophication, freshwater** | Central | 17,5 | 3,6 | 3,4 | 21,6 | - |
| | Mediterranean | -10,1 | 1,1 | 1,0 | 1,4 | - |
| | Northern | -0,5 | 4,3 | 5,4 | 1,7 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Photochemical ozone formation** | Central | 16,1 | 2,6 | 3,7 | 2,6 | - |
| | Mediterranean | 7,0 | 2,8 | 3,8 | 0,8 | - |
| | Northern | 1,6 | 9,6 | 17,5 | 0,6 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Resource use, fossils** | Central | 3,3 | 2,0 | 6,1 | 5,0 | - |
| | Mediterranean | -28,4 | 1,8 | 5,1 | 1,5 | - |
| | Northern | 3,3 | 7,4 | 23,7 | 1,7 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Resource use, minerals and metals** | Central | 0,5 | 0,2 | 0,1 | 0,6 | - |
| | Mediterranean | -2,8 | -0,1 | -0,1 | -0,2 | - |
| | Northern | -0,3 | 0,4 | 0,5 | 0,2 | - |
| | Non-renewable | - | - | - | - | 100 |
| **Water use** | Central | -47,1 | -5,5 | -5,4 | -16,0 | - |
| | Mediterranean | -79,2 | -5,3 | -5,3 | -5,2 | - |
| | Northern | -8,8 | -23,8 | -25,9 | -7,5 | - |
| | Non-renewable | - | - | - | - | 100 |

## References


1. Eurostat (2023). *Sewage sludge production and disposal*. [Data set]. https://ec.europa.eu/eurostat/databrowser/view/env_ww_spd/default/table?lang=en&category=env.env_wat.env_nwat (Accessed on 23 July 2024)
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