# Environmental assessment of the agronomic recovery of post-treated digestates

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# TD-P-Déchaux

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## 1. Objectives

The environmental assessment of digestate (residue from anaerobic digestion) post-treatment pathways is seen from a new perspective: it is no longer a residue management but an agronomic pathway which is environmentally assessed. Furthermore, a general analysis of the post-treatment pathways is targeted. Life Cycle Assessment (LCA) is used to compare the post-treatment pathways of four types of digestates: two issued from farm digestion plants treating mainly agricultural waste, one from a collective biogas plant treating residues from various origins, and one issued from biowaste digestion.

## 2. Methodology

Post-treatment pathways are compared in terms of the agronomic value of the produced and spread products. In order to realize this comparison, a LCA has been performed. LCA is an environmental assessment tool which allows the quantification of potential environmental impacts of the studied system through its whole life cycle [1]. To compare and assess different systems, the LCA practitioner has to build a functional unit translating the common function between the different systems. For this study, the function is based on the fertilizing and soil improving value of the spread product (raw or post-treated digestate). The fertilizing value is based on the amount of available nitrogen for plants and the soil improving value is based on the amount of organic matter that remains to the soil. This amount is quantified as residual carbon. A functional unit based on "to provide X mass of available nitrogen and Y mass of residual carbon to the soil, from an annual production of Z mass of raw digestate" has been deployed to the various pathways studied in the project. Those are 1/ simple pathways such as raw digestate direct spreading; spreading of the solid and liquid phases and 2/ advanced pathways such as composting or drying of the solid phase, and membrane filtration of the liquid phase. To compare two pathways which do not provide the same quantities of available nitrogen and organic matter to the soil, the boundary expansion rule was applied. When comparing two systems, it was then chosen to complete the fertilizing value of the post-treatment pathway presenting a nitrogen deficit by nitrogen mineral fertilizer addition. In the same way, the soil improving value of pathway with organic matter deficit was completed by peat addition.

Most of data concerning digestate characteristics were supplied by analysis and experiments performed along the project ANR DIVA. They are relative to the matter characterization of the products, the gaseous emissions ($CO_2$, $NH_3$ and $N_2O$) during the composting and drying steps or following the spreading on soil, the determination of the fertilizing and soil improving values of the soil-provided products. Matter and energy data issued from four typical sites of the studied pathways in France. Literature data and databases were also used.

GaBi6 software was used for the LCA. CML-IA (version 2013) was the characterization method mainly used in this study for the quantification of the majority of the environmental impacts (CML2002 (2011 updating) was used for the resource depletion category).

## 3. Results and discussion

### 3.1 Comparison of the post-treatment pathways

Results showed that the environmental impacts of the raw digestate direct spreading pathway and the phase separation followed by solid and liquid spreading pathway (two pathways which are not so differing) are generally close. This was not true for the resource depletion and the acidification impact categories, for which the phase separation followed by solid and liquid spreading pathway was more impacting, because of the boundary expansion (addition of mineral fertilizer and peat).

Pathways with an advanced post-treatment (composting, drying and/or membrane filtration) were more impacting than pathways with a limited post-treatment regarding resource depletion, smog, toxicity and ecotoxicity. They presented the same order of magnitude regarding three concerns of anaerobic digestion: acidification, eutrophication and climate change.

### 3.2 Impact of the background activities

Background activities are support activities required by the post-treatment pathways, but which are not directly controllable within the pathway. Those activities, such as the production of electricity (used for phase separation, membrane filtration, air treatment) or the production of chemicals (sulfuric acid for drying and membrane filtration, polymer for centrifugation…), were responsible for the impacts on resource depletion, and explained a part of the impacts on smog, ecotoxicity and acidification.

### 3.3 Impact of the foreground activities

Foreground activities are leeway activities, that is to say activities which are controllable within the post-treatment pathway. Regarding smog, the impact of the foreground activities was due to the transport emissions. Regarding climate change, eutrophication, acidification, toxicity and ecotoxicity, the impacts of the foreground activities were mainly related to the subsequent spreading emissions and fate of the spread product.

Impacts of two advanced post-treatment pathways, studied in the project, are further detailed below: 1/ solid phase drying and membrane filtration of the liquid phase applied to digestate from a collective biogas plant; 2/ composting of the solid phase applied to the digestate from biowaste.

**Example number 1 of a detailed pathway:** Solid phase drying and membrane filtration of the liquid phase applied to a digestate from a collective biogas plant.

In this advanced post-treatment pathway applied to a digestate from a collective biogas plant, raw digestate is first centrifuged. Then the solid phase is dried and spread 200 km from the installation site. The liquid phase undergoes ultrafiltration, followed by reverse osmosis. The retentate and the concentrate respectively issued from those two steps are spread next to the installation site. Figure 1 shows the environmental impacts calculated for the foreground activities of this pathway.

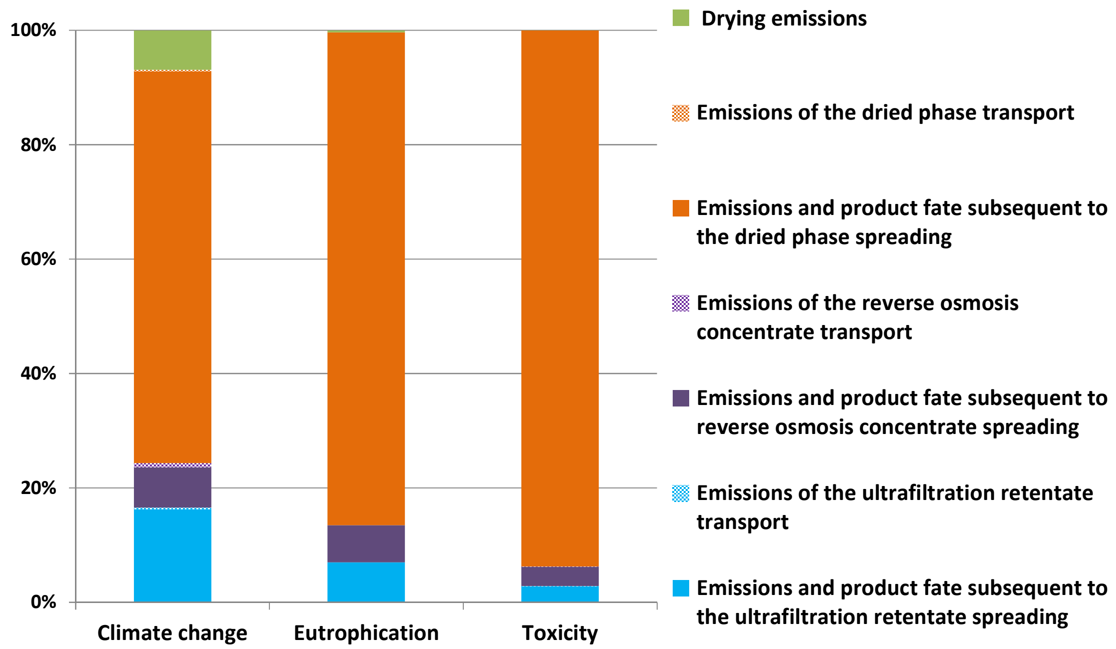


Figure 1: Relative contribution of the foreground activities to the evaluated impacts for the solid phase drying + membrane filtration of the liquid phase pathway applied to a digestate from a collective biogas plant

As shown on Figure 1, emissions and product fate subsequent to the dried phase spreading explain most of the impacts of the assessed impacts.

Climate change is due to long term biogenic $CO_2$ emissions from the dried product. Those emissions are linked to the high carbon content of the dried product (437 g of C/ kg of dried matter). Even when not considering the biogenic $CO_2$ emissions, the conclusion is the same (i.e. preponderance of the dried product) because the $N_2O$ volatilization potential of the dried product is high in comparison to those of the retentate and the concentrate products.
Eutrophication is mainly due to the phosphorus content of the dried phase. This is explained by the centrifugation step, where 85% of the phosphorus goes to the solid phase, while only 15% goes to the liquid phase.

Selectivity at the separation step is also true for toxicity. At this step, most of the trace metals are recovered in the solid phase, resulting in a major contribution of the dried phase spreading to toxicity.

**Example number 2 of a detailed pathway:** Solid phase composting applied to digestate from biowaste.

In the solid phase composting pathway applied to digestate from biowaste, raw digestate is first filtered, sieved and centrifuged. Then the solid phase is composted and spread 30 km from the digestion plant. The liquid phase is treated in a wastewater treatment plant, near the digestion plant. Table 1 indicates the main flows responsible for the environmental impacts of this pathway foreground activities.

Table 1: Identification of the main flows responsible for the impacts of the foreground activities for the composting pathway of digestate from biowaste

| Impact category | Contributing flows | Flow contribution to the impact | Flow contribution to the main steps of the pathway |
|---|---|---|---|
| **Climate change** | Biogenic $CO_2$ | 41% | Compost spreading |
| | Biogenic $CO_2$ | 32% | Composting |
| | $N_2O$ | 20% | Composting |
| **Acidification** | $NH_3$ | 83% | Composting |
| | $NH_3$ | 5% | Compost spreading |
| **Eutrophication** | P | 85% | Compost spreading |
| | $NH_3$ | 8% | Composting |
| **Toxicity** | Trace metals | 100% | Compost spreading |
| **Ecotoxicity** | Trace metals | 100% | Compost spreading |

As presented in Table 1, emissions during the composting step and emissions subsequent to the compost spreading are responsible for the impacts of the foreground activities.

Biogenic $CO_2$ emissions during composting and after compost spreading, such as $N_2O$ emissions after compost spreading explain the major part of the climate change impact.

$NH_3$ emissions during composting cause the potential acidification emissions. This point could be improved by capturing exhaust air from the composting process and by treating it via a sulfuric acid washing, which could drastically reduce ammonia emissions. On the other hand, this would require the production of sulfuric acid.

Eutrophication is mainly due to the phosphorus content in the spread compost. The $NH_3$ emissions contribution during composting is limited to this impact, and could be reduced, as suggested above.

Trace metals in the spread compost explain the impacts on toxicity and ecotoxicity.

## 3.4 Results about the methodological implementation

### About the functional unit implementation

Using LCA requires a rigorous implementation, which is put to the test here by being applied to digestate post-treatment management. It has been identified via these assessments that the identification of the functional unit, basis of a LCA, relies on the identification of the post-treatment function, which does not mark a consensus between stakeholders. Indeed, the post-treatment interest depends on local conditions. It could be as various as producing a fertilizer, producing a storable or spreadable product, exporting a product, producing a product easy to handle, or producing a product which is spreadable at different periods of the year. Thus, in order to apply LCA for digestate post-treatment assessment, the objective of the planned post-treatment should first be clearly discussed. This implies that results could strongly differ between the post-treatment of two digestates which have similar technical characteristics and are managed by similar technologies, but for which the context differs. A first conclusion here is that, based on the assessments of the DIVA project, the environmental evaluation of post-treatments via LCA cannot be generalized.

### Influence of the boundary expansion rule

The study showed a very limited influence of the boundary expansion in the comparison of the post-treatment pathways (addition of mineral fertilizer or peat when it is necessary according to the functional unit). This influence is only noticeable for resource depletion and acidification in the case of agricultural digestate, and for acidification and eutrophication in the case of a digestate from a collective biogas plant. This is explained by the fact that expanding the boundaries requires the production and application of a consumable, a nitrogen mineral fertilizer for which the subsequent $NH_3$ and $N_2O$ emissions after application have been considered.

## 4. Conclusion and outlook

Results showed that the environmental impacts of a simple post-treatment (phase separation followed by spreading of the solid and liquid phases) are close to those of a direct spreading pathway. Nevertheless, if the choice of an advanced post-treatment cannot be motivated by environmental defenses regarding resource depletion, smog or ecotoxicity, it can be argued about climate change, eutrophication and acidification.

More investigations should be done to better reflect the environmental benefits of post-treatment, both from the application point of view and from the research point of view in LCA. More reflection on the post-treatment interest should change the results and change the system boundary definition. Improving the consideration of the agronomic value of the spread products should also improve the LCA results. More site-specific assessments could permit to improve the assessments, by considering the specific needs of the cultures to grow, such as the characteristics of the spreading sites. On the LCA point of view, it is expected that the development of spatial and temporal differentiation will improve further assessments, by taking into account the local specificities of the spreading.

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**References**

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