Characterization of digestates: do they fit with soil improvers or fertilisers standards?

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Abstract
Management of digestates could be a key issue for the future development of the anaerobic digestion market. Actually, a clear definition of their status and quality is necessary to secure valorization opportunities for all of the treated organic matter. In this study, three digestion plants have been followed for one year. Raw, solid and liquid digestate were sampled and characterized five times along the year in order to state on their quality and to compare it to the existing standards for soil improvers and fertilisers. In a French context, digestates do not fulfil the product specifications of soil improvers or fertilisers.

Introduction
In 2008, the revision of the Waste Framework Directive implemented the "waste hierarchy" and set an order of preference that has to be adopted for waste management, namely: prevention, preparation for re-use, recycling, other recovery and finally landfilling. Thus, biological treatment technologies have been developing for many years. Anaerobic digestion is of great interest because it produces renewable energy and the residue, digestate, can be used as a soil improver or as an organic fertiliser depending on the post-treatment. Many authors agree on the fact that when considering an agricultural recycling as a soil improver, digestate requires a maturation phase [1]. One of the key issues for the anaerobic digestion market is to optimize the management of digestates in order to allow a clear definition of their status and to secure valorization opportunities for all of the treated organic matter. The literature provides relatively little information concerning the quality of digestates [2-3]. The objective of the presented work was then to characterize digestates along one year and to discuss their potential status (waste or product) regarding existing standards for soil improvers and fertilizers.

Material and Methods
Anaerobic digestion plants
Digestates from four digestion plants have been characterised along one year, about once every two months. First plant treated solid cattle manure (AGRI1) through a mesophilic digestion with a residence time of about 60 days. The second plant (AGRI2) digested a mix of solid cattle manure, cattle and pig liquid manure and solid residues from agro-food industry through a mesophilic digestion with a residence time of about 30 days and a post-digestion varying from one to 6 months. The third one (TERR) co-digested waste from food-industry (sludge, rumen content, greases) with pig manure, through a mesophilic process with a residence time of about 60 days and a post-digestion about 2 weeks. The last one (BIOD) digested source sorted organic fraction of municipal solid waste (SSOFMSW) and green waste through a thermophilic digestion with a residence time around 3 weeks.

Substrates sampling
On each studied plant, digestates were sampled five times over a year. Three types of digestate were sampled each time: in the digester or post-digester (Raw digestate) and after phase separation (liquid and solid digestates).

Characterizations

All digestates were characterized for classical chemical parameters and for all the agronomic, environmental and biological parameters required by the French standards specifications for soil improvers and organic fertilizers [4-6]:

- pH; dry matter and organic matter content; total carbon; total nitrogen; organic nitrogen; nitric nitrogen; ammonium ; phosphorus, potassium
- Impurities (only on raw digestates) ; Heavy metals ; PAH and PCB ; *Escherichia coli; Clostridium perfringens; Streptococci; Salmonella; Listeria monocytogenes* ; helminths eggs.

Results

Digestates mean chemical characteristics

Digestates showed basic pH around 8 for raw and liquid digestates and around nine for solid digestates (Figure 1). Dry matter content of the digestates depends on the characteristics of the treated waste loaded in the digester but also on the efficiency of the phase separation process (Figure 2). As an example with a screw press as for AGRI 1 and 2, only 50 % of the dry matter goes into the solid digestate so that the liquid digestate still contains a high load of solids. On the other hand plants as TERR and BIOD have much more sophisticated (respectively centrifugation and screw press + sieving + centrifugation) separation processes so that up to 80 % of dry matter goes into the solid phase.

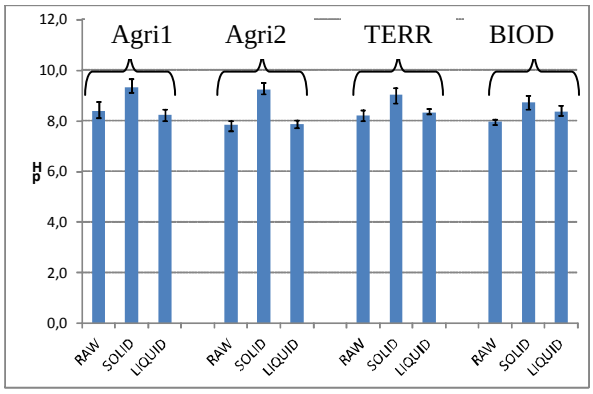

Figure 1. Mean pH of digestates

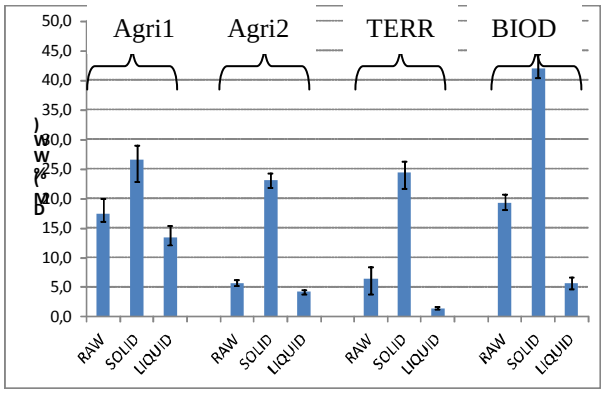

Figure 2. Mean DM content of digestates

Organic matter, carbon and nitrogen contents (Figure 3) also varied from one substrate to another. Nevertheless, as shown on figures 1-3, the five digestion plants produced quite stable quality of digestates considering the variability of the substrates entering the digesters. Indeed, standard variation for all tested parameters along one year was most-of the time under 20%.

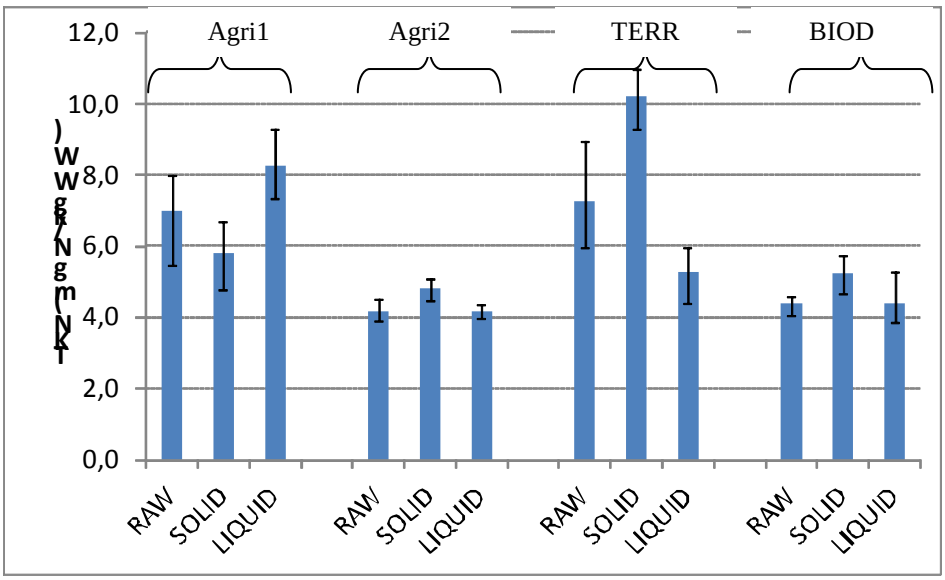

Figure 3. Mean TKN - content of digestates

As digestion process consumed carbon for biogas production while retaining nitrogen, C/N ratio of digestate is low (Table 1), especially for raw and liquid ones. The ratio of ammonia upon Total nitrogen ranges between 38 % for BIOD raw digestate to 72 for TERR raw digestate which has undergone the longest residence time in the digester. Main part of ammonia is directed to the liquid phase as shown in table 1: $NH4^+$/TKN ratio is no more than 36 % in solid digestates.

Table 1. Mean C/N and $NH4^+$/TKN ratios for digestates

	AGRI1			AGRI2			TERR			BIOD		
	Raw	Solid	Liquid	Raw	Solid	Liquid	Raw	Solid	Liquid	Raw	Solid	Liquid
C/N	8.6	16.3	5.7	5.6	21.2	4.1	3.5	9.3	1.5	12.7	23.7	5.4
$NH4^+$/TKN (%)	49	35	59	67	36	70	72	31	875.4	38	14	53

Comparison to existing standards: French context

In the French context digestates can only be considered as a product if they fulfil the specifications of the standard for soil improvers NFU 44-051 or NFU 44-095 [4, 6] after a composting treatment. Nevertheless anaerobic digestion operators are asking for a product status for digestate without the obligation for a composting post-treatment.

Our data showed that studied digestates do not fulfil the agronomic specifications for soil improver standard (Table 2). First problem concerns the dry matter content. Even solid digestates are too wet (< 30% of WW), inducing by the way a too low organic matter content. Moreover regarding NFU 44-051, the ammonia content for digestates is too high compared to the specification on ammonia upon total nitrogen ratio. Second type of problem concerns heavy metals. Agri1, Agri2 and TERR exceeded specifications for Copper, Zinc and Cadmium content. Finally, BIOD digestate presented a problem with impurities. Even issuing from a source separated collection, the treated biowaste on the BIOD plant was contaminated with plastics.

Biological parameters are not a problem when compared to standard specifications. Indeed, only the *Clostridium perfringens* content does not complies with standard which only concerns TERR digestates. Moreover, analysis of PAH and PCB did not exceed the standard threshold.

Table 2. Correspondence between studied samples and French standard specifications for soil improvers

Criteria	Samples which comply specifications	NFU 44-051	NFU 44-095 (only TERR concerned)
DM(%WW)	BIOD solid	≥ 30%	≥ 50%
OM (%WW)	BIOD solid	≥ 20 à 25%	≥ 20%
OM(%DM)	All	-	≥ 30%
N ou P_2O_5 ou K_2O_5 (%WW)	All	< 3%	< 3%
N + P_2O_5 + K_2O_5 (%WW)	All	< 7%	< 7%
N-NH4+/NT	BIOD solid	<33 %	
C/N	Agri1, BIOD et OMR Raw + all solid digestates	> 8	-
MO/N_{orga}	TERR OK	-	< 40
Viable Helminths eggs	All	Abs/1.5 g	
Salmonella	All	abs/1 ou 25g	abs/1 ou 25g
Listeria monocytogenes	All	-	abs/1 ou 25g
E. coli (UFC/gWW)	TERR OK	-	$< 10^3$ à 10^4
Cl. Perfringens (UFC/gWW)	-	-	$< 10^2$ à 10^3
Streptococci (UFC/gWW)	TERR OK	-	$< 10^5$

When considering standard for fertilisers NFU 42-001 [5], digestates do not contain enough fertilising elements (< 3% of WW). Thus the actual French standards for agronomic products are not adapted to consider digestates.

At the European level, some countries have already edited specific standards or guidelines for digestates as the RAL GZ 245 in Germany or the PAS 110 in Great Britain. These quality standards generally authorize lower organic content for soil improvers (OM> 30% of dry matter in RAL GZ 245) or lower content of fertilizing elements. Considering such specifications all the studied digestates can reach a product status.

Conclusion and perspectives

Digestates composition differed from one plant to another mainly concerning nitrogen content and nitrogen forms, with more ammonia for anaerobic digestion with longer residence time. However, our study showed that the quality of the digestate over a year of operation is quite stable even if the digester is fed with varying substrates.

Compared only to agronomic specifications of French standards NF U 44-051 and NF U 44-095, sampled digestates cannot be accepted as soil improvers because of their low dry matter content. Solid phase of digestates have most of the time a too low organic matter content. Digestates can neither be recognised as fertilisers considering the NF U 42-001 specifications because N, K_2O or P_2O_5 are always lower than 3%. Thus, in the French context, digestates cannot be considered as a product withinthe existing standards and need a post-treatment.

It is important to stress that none of these standards take into account the real agronomic effect of digestates on soil as a specification. Moreover only few scientific works have been done on the effect of digestate upon soil organic matter aggregation or plant fertility. Thus it is rather difficult to state on the good adequacy of existing standards to ensure a real agronomic quality of digestates. The most relevant post-treatment has to be studied regarding the use of the final product. A reflection should also be initiated on the need for a specific standard for digestates.

References

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