State of the art of digestates in France and of their agronomic value

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Abstract
In France, as in several countries worldwide, anaerobic digestion is extensively promoted for the management of organic wastes from various origins like sludge from wastewater treatment plants, food-industry, agriculture (including animal manure and culture residues) and municipal solid waste (including household and green waste). Despite this strong promotion, the status of the digestate remains a problem since it is still considered as a waste by French regulation and can be used only for spreading on land or has to be transformed by composting.
Since digestate composition may differ depending on the origin of the methanised substrates and since several different post-processing steps can be used to change its physico-chemical characteristics, we did a review of the different studies realized so far in France concerning anaerobic digestion main waste streams, digestates composition and agronomical value.

Keywords
Anaerobic digestion; digestate; agronomy; field studies; soil improver

INTRODUCTION

In recent decades, the production of organic waste has continued to grow in France and in most industrialised countries due to the increase in production at the source and the introduction of new collection channels. In this context, the process of anaerobic digestion is nowadays promoted around three main waste streams in order to reduce greenhouse gas emissions and produce green energy: household biowaste and residual household waste, organic waste and by-products of agriculture, and finally organic waste and agro-industrial sludge from wastewater treatment units.

Anaerobic digestion is of great interest because it produces renewable energy, reduces gaseous emissions from waste and produces digestate that can be used as soil improver or organic fertiliser. However, so far, digestate is still considered as a waste by the French regulation and its use in agriculture is limited to spreading. One of the key issues for the anaerobic digestion market is thus to optimize the management of digestate in order to allow a clear definition of its status and to secure valorisation opportunities for all of the treated organic matter.

Since the literature provides relatively little information concerning the quality of digestates (Kupper and Fuchs 2007, Teglia et al. 2011), the objective of the presented work was to make a state of the art of anaerobic digestion in France, regarding figures of the different waste channels, digestate composition, agronomical value of digestate and the different post-treatment processes used for solid and liquid digestates.

FIGURES OF FRENCH ANAEROBIC DIGESTION

In France, the pool of organic matter produced each year is estimated at 15 million tons of waste for the food industry (ADEME-Gaz de France, 2004), 50 million tons of municipal waste (only 10% are currently treated by biological treatment) and about 157 million tons of solid manure for the agricultural sector (Lessirard and Quevremont 2008). The most common application of anaerobic digestion is for industrial effluent and urban sludge treatment but new plants are under construction / start (ten) or study (one hundred) in the field of household waste and the agricultural sector (Table 1).

Table 1. Plants and biogas production in France in 2011 (data from ATEE, Club Biogaz 2011)

Sector	Number of plants	Waste treated (T of $/ year)	Biogas production (NM^3/year)	Cumulated electric power (MW)
Industry	80	149 400	57 000 000	1 765
Wastewater treatment	60	17 000 000	140 000 000	12.2
Agriculture	48	103 500	34 652 000	9.6
Household waste	9	20 000	64 000 000	16.4

$ is dry matter for Industry and Agriculture, people equivalent for wastewater and raw matter for household waste

Concerning industry, most facilities have been designed to treat the organic fraction of food-industry effluents. In these plants, biogas is upgraded to produce heat that is consumed on site. In the area of wastewater treatment, anaerobic digestion is used primarily as a method for reducing sludge production and is applied to mixed sludge (primary + secondary sludge). Most of the processes are installed on large sewage plants (more than 30 000 PE). In this context, the biogas is upgraded to produce heat used in the process and sludge drying. In the agricultural sector, anaerobic digestion is applied to manure (slurry, manure) to which other organic co-substrates can be added. A dozen facilities were in operation in 2008, 48 in 2011 and there are more than a hundred projects in design. Biogas is valued almost exclusively by cogeneration. Finally, for household waste, biogas is produced in majority in landfills of non-hazardous waste (301 sites in France, with only 71 collecting biogas in 2010). Production from source sorted or mechanically sorted organic fraction of municipal solid waste and green waste is done in 9 facilities. Biogas is valued by cogeneration on site and sometimes in public buildings.

At all, biogas made 0.44% of the total primary renewable energy produced in France in 2010.

AGRONOMIC VALUE OF DIGESTATE

Characteristics of digestates

Physico-chemical and microbial composition of 150 digestates of various origins compiled in the study ADEME / RITTMO 2011 were aggregated with data from the agricultural sector (Figure 1).

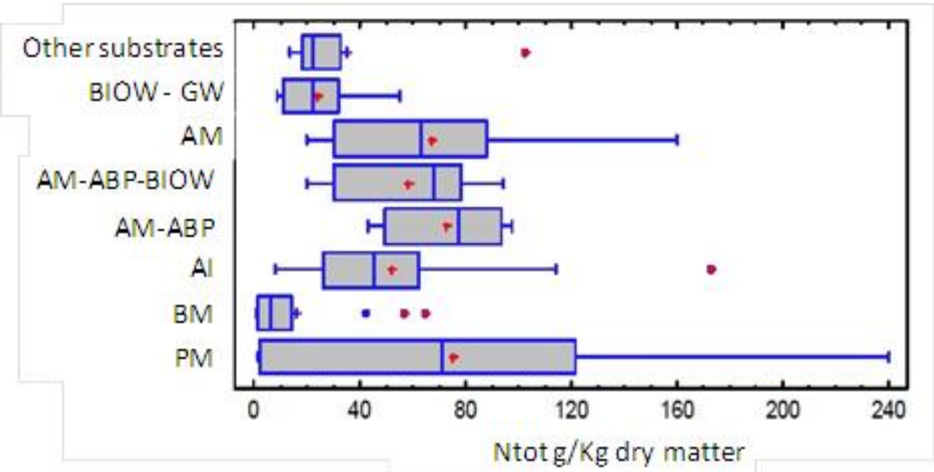

Figure 1. Distribution of total nitrogen (g/kg DM) based on inputs: BIOW, biowaste; GW, greenwaste; AM, mixture of animal manures; ABP, animal by-products; AI, agrifood industry waste; BM, bovine manure and PM, pig manure (from ADEME / RITTMO 2011)

The nutrient composition of digestates differs depending upon the biogas plant. However, no clear relationship could be drawn between substrates and digestates compositions because the data were too dispersed. The data analysis gave a general trend. For nutrients NPK, the higher levels are observed for digestates from anaerobic digestion of pig manure and animal by-products. In contrast, the lower levels are associated with digestates from anaerobic digestion of biowaste, green waste and cattle manure. The essential differences between a substrate and a raw digestate from the same substrate are that the NH_4/Ntot ratio is higher for digestate and the C/N and pH are lower for digestate (not shown).

For microbial characterizations, 37% of digestates from agricultural substrates are classified as "doubtful" on *enterobacteria*, *salmonella*, *E. coli*, *Clostridium perfringens* and *Listeria*, *campylobacteria*, *enterococci* (not shown). An Austrian study (Singer, 2005) highlighted the fact that the introduction of biowaste in anaerobic digesters implied the presence of *Enterobacteriaceae* in the digestate. Similarly, digesters treating oils or fat from food waste had *salmonella*.

Field studies

Overall, French and international literature about field studies on the agronomic value of digestates is poor. Moreover, the data are sometimes contradictory. The global trend is the interest of bioavailable nitrogen in digestate that may increase crop yields compared to undigested substrates (6 to 20% increases for digestate from agriculture waste). Also, Odlare (2008) shows that the use of digestate improves the yields of barley and oats compared to compost. However, the yields are generally lower than those obtained with mineral fertilizers but long-term effect of organic matter degradation can be expected with digestates. Recommendations can be done for the utilisation of digestates such as use of digestate is discouraged on barley too susceptible to lodging. On the opposite, cultures that value the best digestates are rapeseed before plowing, corn/ sorghum before spring plowing and wheat crop up on the end of winter.

The results vary greatly with weather conditions, including cold and wet weather compared to mineral fertilizers. The key points are thus improving the application materials and reference for research to understand the effects of digestate (volatilization, ammonia poisoning, back effect of organic matter).

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