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Review

Overview of manure treatment in France

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ABSTRACT

Manure treatment becomes a focal issue in relation to current EU and national policies on environmental, climate and renewable energy matters. The objective of this desk study was to collect all available data on the treatment of manure from cattle, pig and poultry farms for an overview of manure treatment in France. Specific surveys in 2008 showed that 12% of pig farms, 11% of poultry farms and 7.5% of cattle farms was concerned by manure treatment. Taken together, the treatment of pig, poultry and cattle manure accounted for 13.6 million tons corresponding to 11.3% of the total annual tonnage (120 million tons). The main processes, mostly applied on the farm, were composting (8.5 million tons), aerobic treatment (2.9 million tons of pig slurry) and anaerobic digestion (1 million tons). Other manure treatments, including physical-chemical treatment, were less frequent (0.4 million of m^3). Treated manure was mainly used to fertilize the soil and crops on the farm concerned. Manure treatment can thus be considered to be underused in France. However, anaerobic digestion is expected to expand to reach the European target of 20% of energy from renewable sources. Nevertheless, this expansion will depend on overcoming the constraint requiring registration or normalization of the use of the digestate as fertilizer. Thus, to avoid penalizing farmers, the further development or creation of collective processing platforms is recommended, combined with an N recovery process that will enable the production of organic amendments and fertilizers in an easy marketable form.

Contents

1. Introduction

The livestock sector must respond to the world food demand that can under certain conditions be in conflict with environmental issues and climate change. Indeed, livestock production generates about 1400 million tons of manure annually in the European Union (EU) with the largest production in France (Foged et al., 2011). Manure is generally stored and then spread on agricultural fields (Loyon et al., 2010). Even if manure is a resource for preserving the soil fertility, its management has become one of the main problems for the environment. These environmental effects have been

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widely reviewed and reported (Martinez et al., 2009; Montes et al., 2013; Steinfeld et al., 2006).

The management of the large volumes of manure was identified to cause water pollution and eutrophication by leaching and/or runoff of nitrate/phosphorus, ammonia emissions in addition to air pollution (greenhouse gas (GHG) and ammonia (NH_3) emissions). This is particularly the case of intensive farming concentrated in specific regions (Martinez et al., 2009). The main problem is the excess of nutrients often associated with intensive farms with not enough land to spread the manure. In regions were nitrogen and phosphorus are in excess relative to available land, the export of excess nutrients out of the region can reduce the environmental impact of livestock (Martinez et al., 2009). Farmers must then consider new strategies for manure management to minimize its environmental impact in accordance to its fertilizer value (Petersen et al., 2007). Manure treatment is an alternative to the traditional nutrient management based only on spreading because it produces manure co-products (e.g. anaerobic digestate, separated liquid and solid fractions, compost) differing by their nutrient content from untreated manure.

In this context, treatment may be essential to reduce the risk of losses of nutrients to water resources in regions with intensive livestock rearing where too much manure is produced (Bernet and Béline, 2009). In addition to better management of nutrients, treatment can also reduce gas emissions (Chadwick et al., 2011; Loyon et al., 2007; Montes et al., 2013). Other possible objectives of manure treatment are the removal of pathogens (Martinez et al., 2009), xenobiotic compounds (emerging pollutants), etc.

Many manure processing systems already exist for livestock farming and can be classified as mechanical/physical separation (Burton, 2007), aeration or anaerobic digestion, and chemical methods (Burton and Turner, 2003).

For the European Commission manure treatment techniques become an important tool for the enforcement of regulations regarding nitrate and phosphorus loading of water resources addressed by the EU Nitrates Directive (EEC, 1991) and the EU Water Framework Directive (EC, 2000). Manure treatment is also recommended as part of the reduction of gas emissions (NH_3, GHG) under the Gothenburg Protocol (UNECE, 1999) and the NEC Directive (EC, 2001). Manure treatment is considered as a Best Available Technique (BAT) under the Industrial Emissions Directive (IED (EC, 2010)). Recently, manure treatment by anaerobic process (also called biogas process) is considered as a source of energy within the EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources (EC, 2009).

A recent European survey (Foged et al., 2011) estimated that manure treatment in Europe accounts for around 8% of the total volume of livestock manure produced, with major differences between countries. Data on manure treatment in France are still irregular, widely dispersed and not always synthesized. However, some French government or professional organizations do publish data on manure management. These data come from national livestock surveys or from dedicated surveys of manure management in some regions with intensive livestock farming.

Thus, the objective of this paper was to collect all data on the treatment of cattle, pig or poultry manure to obtain as precise an overview of manure treatment in France as possible. Our main objective was to estimate the proportion of manure that is treated relative to the total amount of manure produced in France every year. The technical characteristics of the treatment (energy consumption, nitrogen or carbon abatement, etc.) is beyond the scope of this work.

Table 1
Estimated annual quantity of manure, nitrogen and phosphorus produced on farms by cattle, pig and poultry in France (tons of fresh manure, pasture not included).

Type of livestock	Total excrement (in tons of fresh manure)	Nitrogen[d] (tons of N)	Phosphorus (tons of P)
Cattle[a]	Solid manure: 68.7 million tons Slurry: 18.2 million tons	1,326,000	100,000[e]
Pigs[b]	Slurry: 25.4 million m[c] Manure: 828,000 tons	143,000	57,800[b]
Poultry[c]	Solid manure: 2.5 million tons Droppings: 0.6 million tons Slurry: 2.5 million tons	127,000	35,000[c]

[a] Capdeville et al. (2015).
[b] Ifip (2010).
[c] Itavi (2013).
[d] Eau France (2014).
[e] Personal estimate.

2. Manure production by the French livestock (cattle, poultry and pig)

According to the French Agricultural census 2010 (Maaf, 2010), 19.5 million cattle, 13.9 million pigs and 221.6 million poultry were counted in France. On the farm itself (not including pastureland) this livestock produces around 120 million tons of manure per year (Table 1) comprising 60.6% solid manure, 38.8% slurry, the remainder being poultry droppings (Capdeville et al., 2015; Ifip, 2010; Itavi, 2013). The corresponding amounts of organic N and P are estimated to be around 1.6 and 0.2 million tons per year, respectively (Table 1). Manure is mainly spread on the soil and on crops. Manure production is not homogenously distributed over the whole French territory. The majority of slurry and solid manure is produced in the north-west (Brittany, Pays de la Loire and Lower Normandy). The concentrated production of manure in a small area results in a N surplus estimated at 902,000 tons with a national average of 32 $kg\,ha^{-1}$ of Utilized Agricultural Area (MEDDE, 2013a,b).

3. French legislation of manure treatment

In France, depending on the farm's livestock thresholds, cattle, pigs and poultry farms are subject to (i) Departmental Health Regulations (RSD) or (ii) Classified Installations for Environmental Protection (ICPE). Depending on their geographical location, farms are also covered by European directives (Nitrates Directive, Water Framework Directive) which introduced additional requirements for land application of manure in certain areas. In France, the majority of farmers recycle manure on their farm by spreading, but livestock manure is also treated for various reasons: (i) to transform manure into organic amendment (NFU 44-051, AFNOR, 2016a) or organic fertilizer (NFU 42-001, AFNOR, 2016b) for commercial purposes (or not because in France manure must have the status of an organic product to be saleable off the farm), (ii) as a way of reducing N surpluses in some areas to meet the regulatory requirements of the Nitrates Directive concerning N fertilization, (iii) as mandatory under the Nitrates Directive for farms located in Nitrate Vulnerable Zones (NVZs) that produce specific N surplus which are defined regionally, and (iv) mandatorily under the Water Framework Directive in the river district "Loire-Bretagne" to respect the balance of P fertilization. Manure treatment, especially anaerobic digestion, is also recommended and receives financial support in some regions, mainly in Brittany, where manure production is very high, and under occasional plans that aim to restore the quality of water (MEDDE and MAAP, 2010, 2013). In France, when reporting NH_3 emissions under the IED directive, farmers can declare a 70% reduction in emissions if they use nitrification-denitrification manure treatment, and anaerobic digestion treatment with or without phase separation (MEDDE, 2015).

4. Main manure treatment applied in France

No official databases on manure management exist in France but government and some professional organizations do publish data on the management of livestock manure. For example, the statistics service (SSP, Agreste) of the Ministry of Agriculture and Food has conducted surveys of buildings used for livestock and manure management. Unfortunately, the data from these surveys date back to 2008 and do not include details on manure management. More recent data exist but are only for some regions. We did our best to supplement these data by analyzing a number of relatively recent documents (administrative and professional assessments or surveys), expert reports to the Ministries of Agriculture or of the Environment, technical reports or articles and professional press. Nevertheless, it is important to bear in mind that this overview is not exhaustive and includes a margin of error.

According to the surveys conducted in 2008 (Agreste, 2008a,b,c), manure was treated on 12% of pig farms, 11% of poultry farms and 7.5% of cattle farms. However, only questions concerning composting were asked on cattle farms. Poultry farms treated manure mainly by composting (53.7% of farms that treated their manure), drying (15.1% of farms that treated their manure) and separation (2.3% farms that treated their manure). A total of 13.6% of farms that treated their manure reported using another form of treatment but without specifying which. Concerning pig farms, more detailed analyses of the surveys conducted in 2008 (IFIP, 2010) showed that treatment concerned 4.2 million m^3 of slurry in 550 units (Ifip, 2013), 68.6% in Brittany and 14.2% in the ‘‘Grand Ouest”, two regions with intensive manure production. Manure treatment was mainly aerobic in large units (64.6% of the total volume of treated manure and 45.4% of farms that treated their manure). The second most widely used type was physical-chemical treatment (10.7% of the total volume of manure and 16.4% of farms that treated their manure). Finally, composting slurry on straw accounted for 5% of the total volume of manure. Treatment usually took place on the farm (75% of the total volume of treated manure and 68% of farms that treated their manure) while 32% of farms shared manure treatment (25% of treated manure) managed by a group of farmers or by a service provider. In Brittany, 74.3% of farms used aerobic treatment, accounting for 84.5% of the total volume of treated manure in France. In other regions, only 14.5% of farms used aerobic treatment, accounting for 21.2% of the total volume of treated manure in France.

In the following sections, we review the main treatments applied in France for which data were available.

4.1. Aerobic treatment

The aim of aerobic treatment is nitrogen removal by nitrification and denitrification that could be obtained with alternating (in space or in time) of anoxic and aerobic phase or with low levels of aeration (Beline and Martinez, 2002). This process results in a dinitrogen (N_2) emission and sometimes under unfavourable conditions in a nitrous oxide formation (Loyon et al., 2007). In France aerobic treatment with nitrification/denitrification of manure was highly developed in the years 1998–2002 for the treatment of pig slurry with a significant economic cost to farmers and the public authorities to reduce the flow of nitrogen to the aquatic environment (Levasseur and Lemaire, 2006).

Around 550 slurry treatment units, mainly for pig and duck slurry, are registered in France and treat 4.2 million m^3 of slurry per year (IFIP, 2010, 2013). Among these treatment units, the majority of the aerobic treatment units are located in Brittany (389 units, 2.9 million m^3) due to the high density of pig production and resulting surplus N (UGPVB, 2014; personal communication UGPVB, 2016). Eighty percent of these aerobic treatment units are implemented on farm and process of pig slurry. Aerobic biological treatment was first developed in Brittany to reduce the N surplus and was then supplemented with additional mechanical separation to manage excess P (Bernet and Béline, 2009). Different aerobic treatment units exist, with or without separation of the slurry by centrifuge or by screw (Béline et al., 2008). Similarly, the sediment of aerated slurry can be separated mechanically. In general, the products of the manure treatment contain less N than the raw slurry and are used by farmers to fertilize their own crops. The residues of separation can also be exported after composting on the farm or on a collective platform.

4.2. Anaerobic digestion

Anaerobic digestion is the process of degradation of organic material by microorganisms in the absence of oxygen, producing a biogas mainly composed with CH_4 and CO_2 (Nasir et al., 2012). Anaerobic digestion on farm allows the production of renewable energy from biogas, recoverable locally into heat and/or electricity. Manure used for anaerobic digestion becomes a compound called digestate rich in nutrients, which makes it a potential substitute to chemical fertilizers in agriculture (Tambone et al., 2015)

The French government has decided to promote agricultural biogas sector, setting an electricity feed-in tariff produced from agricultural biogas, supplemented by investment aid. At the end of 2013, the use of one million tons of livestock manure was planned for methane production (ADEME, 2013a), 65% (672,000 tons) in on farm unit (140 units), 22.5% (227,000 tons) in centralized agricultural units (6 units) and 13% (131,000 tons) in centralized waste-type units (21 units). The regions most concerned are Brittany, Pays de la Loire, Lower Normandy and Lorraine. More recent data (Biorefine, 2015) showed that in April 2015, 185 on farm units of biogas and 23 centralized units were in operation (tonnage not given). Thus, according to the 2013 data (ADEME, 2013a), about 0.8% of the national tonnage (Table 1) were used as inputs for biogas units (cogeneration). Eighty percent of anaerobic digestion on the farm or in centralized manure treatment units is done by a liquid process. According to the 2013 data (ADEME, 2013a), the manure generates 788,000 MWh in on farm or centralized units. In 2030, manure could represent 22 TWh of primary energy through the extension of biogas plants (ADEME, 2013b).

In France, the digestate is considered as waste conforming to the European directive (EEC, 2008) or is transformed into a registered or standardized organic product. As waste, the digestate has to be applied on the soil following a specific spreading scheme. If the digestate meets the requirements described in a standard (NFU NFU 44 051 or 44 095), it can be sold. According to the 2013 data (ADEME, 2013a), half the farms with on farm units planned to treat 65% of the digestate by phase separation. All collective biogas plants planned to treat digestate, mainly by phase separation. Phase separation is mainly by screw press or centrifugation (Ingremeau, 2014). The treatment of the liquid phase resulting from anaerobic treatment is mainly aerobic (Biorefine, 2015). The treatment of the solid phase is mainly by composting (with forced ventilation or mechanical turning) and by drying (conveyor belt) (Biorefine, 2015). The expansion of the digestate drying processes is limited due to a lack of technical and economic references on these technologies (ADEME, 2010). In France today, only one digestate drying process is in use for poultry manure, which is based on dehydration on a conveyor belt (ADEME, 2010) and the procedure for registering a digestate is long and costly. To date, only three cases have been approved (Ingremeau, 2014).

4.3. Composting

Composting is a traditional management process used since long time to decompose the manure organic matter by microbial aerobic process. The main reasons of composting are to recycle nutrients excreted by animals, stabilize organic matter before its transport and use and reduce manure pathogens (Bernal et al., 2009). Done in static piles with natural aeration composting manure is a low-cost and low-energy process that can be applied on small to medium-sized farms (Oudart et al., 2015).

Because the transfer of fresh manure is prohibited in France, composting is one way to comply with N and P regulations. This technique does not reduce P but composted manure is standardized and becomes exportable as an organic amendment (NFU 44-051) or organic fertilizer (NFU 42-001). In 2011, 4.2 million tons of compost were spread on soil and on crops (Houot et al., 2014). Based on a mass loss of 50% during composting (Bernal et al., 2009), the amount of manure being composted is estimated at approximately 8.4 million tons of fresh manure (11.5% of the total solid manure produced in France, Table 1). As mentioned above, composting is practiced on 0.8% of pig farms, 6.5% of cattle farms and 6.5% of poultry farms. On pig farms, 5.8% of storage areas for solid manure are used for composting (IFIP, 2010) representing a total volume of around 39,000 m^3 of compost. Recently, research revealed an interest in composting the solid fraction resulting from V-shaped scraped slurry of fattening pigs (Loussouarn et al., 2015). Slurry composting on straw accounts for only 0.7–1.5% of pig farms (Bioteau et al., 2010). However in certain circumstances, composting slurry with other waste is another approach compared to biological treatment (IFIP, 2013). According to the same reference, straw and green waste are mainly used in France. Two methods have been developed, the "Guernevez" (Synagri, 2016) method on the ground, and the "Isater" (Evalor, 2016) method on a concrete platform with collection of the liquid phase. Composting is mainly done in windrows with turning or with forced aeration. Vermicomposting also exists but is very marginal. On poultry farms, composting with inoculation of microorganisms is currently being evaluated in research programs. Manure, generally from cattle, is usually composted on the farm, frequently with a turning machine. Another form of livestock composting is co-composting, based on a territorial partnership between a farmer or group of farmers and local communities. This is mostly joint processing of manure and of the green waste produced by the community. Co-farm composting takes place either at the end of field or on stabilized platforms. Composting is also practiced on some industrial platforms for the production of organic amendments (ADEME, 2015). In 2005, only 3% of organic wastes entering the industrial platforms were animal manure (ADEME, 2007).

4.4. Other treatments

Other treatment processes for pig slurry are available on the market (Techno-One, Smelox©) but are rarely used (IFIP, 2013). The Smelox© (fixed or mobile) technique is classified as a physical-chemical treatment that includes phase separation by a centrifugal decanter and volatilization of ammonia N from the liquid fraction. The N is then converted into N2 by catalytic combustion. Its cost (over 500,000 euros) (IFIP, 2013) limits its use to farms that produce and treat more than 20,000 m^3 of manure annually or to be shared among farmers, or used as mobile units operating as service delivery. The Techno-One process involves drying the slurry using the air extracted from the piggeries and is more suitable for small volumes (IFIP, 2013). The liquid manure can also be separated mechanically without aeration of the liquid phase. This is mostly done by centrifugation, a compacting screw and vibratory screen (Loussouarn and Lagadec, 2011). Fixed or mobile systems separate the suspended solids containing P from the liquid phase of the manure. In Brittany, separation accounts for less than 1% of processing units (personal communication UGPVB, 2016).

Table 2
Estimated quantity of pig, cattle and poultry manure treated by the main processes currently used in France.

Treatment	Quantity of manure treated
Composting	8.4 million tons
Aerobic treatment	2.9 million m^3
Anaerobic digestion	1 million tons
Physical-chemical treatment	0.4 million m^3
Other	0.9 million m^3

5. Discussion

According to the results summarized in Table 2, the amount of treated manure is estimated at 13.6 million tons corresponding to 11.3% of total annual tonnage (120 million tons). The treated manure is mainly used to fertilize the soil and crops on the farms concerned. Indeed, in 2011 only 250,000 tons of treated manure (Houot et al., 2014), mainly pig manure, poultry manure and poultry dropping exported from Brittany as organic fertilizers for other farmers, growers, market gardeners, winemakers. It therefore appears that manure treatment is underused in France. Manure is mainly treated due to N surpluses in two regions (Brittany, Pays de Loire). One constraint to the further development of anaerobic digestion is that agricultural use of the digestate requires registration or normalization to become an amendment or an organic fertilizer (MAAF and MEED, 2012). However, anaerobic digestion will expand because it allows better manure management and maintains the N, P, K manure content. The price of electric cogeneration is also another positive reason (MAAF and MEED, 2012). In France, it is planned to build 1000 anaerobic digestion plants by 2020 for the treatment of agricultural feedstock including manure. Cattle manure represents a significant reservoir for this type of processing (Capdeville et al., 2015). Different analyses of the valorization of N manure stress the need to transform manure into registered or standardized products to facilitate transport and use outside the spreading plan, and to give the products a commercial value (ADEME, 2014a; MEDDE and MAAF, 2013). Manure treatment will also facilitate P management. These same analyses recommend promoting processes that reduce N losses by developing or creating collective processing platforms (composting, drying, etc.) associated with N recovery to produce organic amendments and fertilizers in a marketable form like pellets. Nevertheless, tools or legislation are needed in France to enforce the use of manure treatment. Indeed, up to now programs to combat diffuse agricultural pollution are mainly based on education and voluntary actions by producers which seem to be marginally effective (Le Goffe, 2013).

6. Conclusion

Our desk study show that manure treatment is considerably underused in France. Anaerobic digestion is expected to expand to achieve the European target of 20% of energy from renewable sources. However, expansion will depend on overcoming the constraint to the use of the digestate as fertilizer, i.e. that the product requires registration or normalization. Thus, to avoid penalizing farmers, the further development or creation of collective processing platforms (composting, drying, etc.) is highly recommended, combined with an N recovery process to produce organic amendments and fertilizers in an easy marketable form.

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