Reduction of the pollution load from livestock effluents in the Veneto lagoon drainage basin

October the 4th, 2010
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The RiduCaReflui Project: Effluents as a Resource

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Veneto Agricoltura

Abstract
The management of livestock effluents and the nitrates they contain poses serious financial and management problems for livestock farms in Veneto. The objective of the RiduCaReflui Project “Reduction of the Pollution Load from Livestock Effluents in the Veneto Lagoon Drainage Basin” is to analyze and validate technical innovations and model methodologies for breaking down and recovering nitrogen, with the aim of effectively managing livestock effluents in accordance with the Nitrates Directive.

Introduction
The Ministerial Decree of 7 April 2006 stipulates the criteria and standards for regulating the agronomic use of livestock effluents in conformance with the provisions of the European Nitrates Directive. Each region was required to comply with the European directive regarding the designation of Nitrate Vulnerable Zones (NVZs) of agricultural origin and the placement of restrictions on spreading livestock effluents for agronomic purposes.

By May 2006, the Veneto Region had approved the designation of its NVZs in accordance with the European directives. More than 60% of the Region was classified as “vulnerable”, specifically the Province of Rovigo, the Venice Lagoon Drainage Basin, a strip of land traversing 100 municipalities located in spring recharge areas, Monti Lessini Regional Park, and municipalities in Veneto situated on Lake Garda, along tributaries of the Mincio and in areas that contribute to the pollution of the Po River.

In August 2006, the Veneto Region adopted the Regional Action Programme for Nitrate Vulnerable Zones of Agricultural Origin (which takes into account the provisions of the Ministerial Decree of 7 April 2006) followed by the Regional Council Decision of August 2007 on the Adoption of Implementation Criteria, which completed the region’s regulatory framework.

In Veneto the regional regulations in the Ministerial Degree of 7 April 2006 became mandatory as of January 2007.

The new regulations have created considerable operational difficulties in the agricultural-livestock farming sector in terms of administrative, structural, organizational and management constraints. Following the application of the directive, businesses in the sector experienced significant problems, with the most important being that the concentration of livestock often makes spreading the resulting effluents on agricultural land an unsustainable practice due to the pollution limits in NVZs (170 kg of nitrogen/ha/year). In addition, within the NVZs a temporary ban on spreading effluents was issued, constraints came into effect relating to distances (from surface water, buildings, etc.) and storage regulations were modified in accordance with the calculation criteria stipulated in the Ministerial Decree.

The regional government, aware of the difficulties for operators in the sector, is aiding businesses by providing guidance in fulfilling certain bureaucratic obligations, such as the preparation of the Communications and Agronomic Use Plans required by the Ministerial Decree, and has even produced a dedicated software system.

In addition to financing the present project (RiduCaReflui – Reduction of the Pollution Load from Livestock Effluents in the Veneto Lagoon Drainage Basin), which is being carried out by Veneto Agricoltura, the Veneto Region would like to provide recommendations to farmers (who until recently favoured agronomic use as a disposal solution for livestock effluents) on methodologies and supplementary or alternative systems that can reduce the cost of properly managing effluents in accordance with the Nitrates Directive.

The project will also analyze model methodologies for treating livestock effluents, which provide the most effective recovery of the waste by transforming it into a resource for the environment. The research will also investigate the possibility of using effluents for energy production (production of biogas before treatment) and crop production (producing organic fertilizers by using treatment methods that preserve nitrogen).

The RiduCaReflui Project
The main objective of the project is to create conditions that facilitate the integrated management of effluents, implementing tools that can monitor balances on individual farms and on a regional scale.
The project will include nine actions relating to the following subjects:

- **Survey** of the actual production of nutrients, particularly nitrogen, from livestock farms in the Venice Lagoon drainage basin; thematic maps will be produced.

- **Logistics and consignment** of livestock effluents, analyzing the possibility of delivering untreated effluents to collection centres and investigating possible uses for treated effluents and digestate. The research will also include a study of pilot programmes in Veneto.

- **Analysis of innovative treatment technologies** that can reduce and recover the load of nutrients, particularly nitrogen, and subsequent evaluation of their technical and economic sustainability. The objective of this analysis, which represents the core of the project, is to identify technical and management solutions for reducing the pollution load of effluents, keeping in mind the possibility of utilizing the waste for energy production before it is treated to break down and recover nitrogen.

- **Analysis of economic, financial and management tools** for effluent treatment processes, studying consortium-based and regional management models from the perspective of creating an integrated system.

The abovementioned subjects fall within the context of informative, dissemination and training activities. The Region has stressed these subjects in order to open an efficient communication channel with operators in the sector, associations and organizations operating in the region, and to provide knowledge that can be applied at the regional level by private businesses, consortiums, publicly held companies and local governments.

### Conclusion

The objective of the project is to provide guidelines and optimal models for the integrated management of livestock effluents, including the formulation of protocols for managing and monitoring businesses in the livestock farming sector. The actions are designed to evaluate the technical, regulatory, economic and environmental feasibility and sustainability of the use of innovative effluent treatment methodologies by individual farms, as well as consortiums. There will be an in-depth analysis of the economic aspects, including an investment analysis to determine the financial suitability of certain technological, organizational and market choices for the different farm typologies, as well as a study of the guiding administrative and regulatory aspects for selecting useful financial and regulatory tools to stimulate investment and organizational decision making.

This project will enable the Veneto Region to prepare investment analyses of the different processes and technologies that can be used to manage livestock effluents in accordance with the Nitrates Directive and adopted on a broad regional level.
The knowledge of farming systems for interventions planning and impacts assessment

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Abstract

The “RiduCaReflui” project first Action aims to provide tools for the analysis of structural characteristics and dynamics of the farming sector and the territorial context, useful for planning interventions and assessing impacts. For this purpose, the enhancement of the significant wealth of highly detailed databases collected for administrative purposes was planned; however, such files do not have features that allow their direct use for reporting and monitoring purposes. We tried to give a solution to the problems of integration and systematization of data from different sources in order to achieve a Data Mart not only able to represent the situation of production and use of animal manure, but also to grasp its dynamics. The outcome of the project will be a system of dynamic tabular and cartographic reporting, capable of subsequent updates and optimizations when there will be significant improvement of the quality of available archives.

Keywords

Livestock manure, livestock production, agricultural systems monitoring, Veneto region

Introduction

The development of the livestock sector in the Veneto region was characterized by an increasing specialization that has led to an intensification of the production activity: farm structures oriented primarily to produce animals of high quality and efficiency in economic terms have prevailed, however, they were partially released from agricultural land for the production of green raw materials of farm origin, thus changing the relationship between production processes and use of natural resources. As a result, there are territorial situations characterized by the availability of phytonutrients (nitrogen and phosphorus in particular) from animal manure exceeding the crop needs, thus requiring alternative solutions to the normal agronomic use of manure on site (Crovetto and Sandrucci, 2010).

In this context, the definition of strategies for intervention planning needs first a deep knowledge of the livestock production situation and its local context, not only at present but also by considering its evolution over time.

The first Action of the project RiduCaReflui, wanted by the Veneto Region to identify solutions to reduce the environmental impacts of livestock activities, responds to the concern and the need to build a basic knowledge framework representing the situations and the dynamics regarding livestock manure management in the Veneto region, with particular reference to the “the Venice Lagoon drainage basin” (Bacino scolante nella Laguna di Venezia) and in general in nitrate vulnerable areas.

Indeed, it was noted that despite the several works and territorial analysis conducted on this topic, a constant weakness point is represented by the definition of the cognitive framework of livestock and agricultural production context, whenever necessary, gathered considering non arranged information. This aspect becomes more critical when the analysis cover a vast territory as the Veneto region and can lead to undesirable uncertainty when the results of the analysis are used to sustain decisions-making.

Since the project is still under construction and therefore are not available today the final results of the Action, here are some considerations on the method proposed and the operational path taken to achieve the goals.

Material and methods

The information on production and environmental features that, in the management of livestock manure, are considered necessary to prepare a set of strategic indicators to support the decision-making include the following:

- Location, extent and characteristics of livestock, amount of manure produced and its nitrogen content;
- amount and distribution of crop land used or theoretically available for agricultural use of manure at territory level or exploited by livestock farms;
• adoption of manure treatment processes, both at the farm and consortium level and ability to nitrogen abatement;
• the structural characteristics of local context (vulnerability, the presence of constraints on manure spreading, structure of roads and accessibility etc.);
• Evaluation of impacts on different type of areas considered: Bacino scolante nella laguna di Venezia (the Lagoon of Venice drainage basin), other nitrates vulnerable areas, non-vulnerable areas;

To build the indicators, we chose to exploit the wealth of information that the regional Administration has under the Information System of the Veneto Region - ISVR (Agriculture Registry office, database for agronomic use of manure, cartographic layers, etc.).

It was decided to make the Veneto Region developing the Action 1 of the project, for both the organizational benefits derived from the direct availability of many of the archives relating to the project and for the opportunity to ensure the responsible programming body on the ability to manage and directly process the data needed and integrate them into the regional information system by exploiting all possible synergies to optimize the information system.

The activity is organized in two sub-actions:
the first one related to data collection and organization into a database specially configured with the aim of creating an analysis tool (Data Mart) able to acquire, process and track information using business intelligence tools (Dulli and Favero, 2000);
the second is on the geographical display of data and realization of thematic maps, based on information compiled by the Data Mart realized, properly represented in a GIS (Geographical Information System) environment, already present in the ISVR and accessible via the web: the features and the general geographic information layers already improved, can thus be exploited, by structuring a dedicated gateway to information management of farming sector.

It was necessary to make a preliminary survey of available databases, initially structured for purposes other than those described above, and identify the content available for each, the managing body, the availability and terms of acquisition and other general features relating to the data quality and updating.

The databases considered are:
• Agricultural use of animal manure database (“Nitrates” Communication) (DGR 2439/2007)
• Regional registry for livestock activities (BDR) (DGR 2226/2002)
• Archive statements for the granting of subsidised fuel for agricultural use (DGR 3618/2005)
• Agriculture Regional registry (DGR 3758/2004)
• Regional Land Cover Map
• Archive Project “Probio”
• Archive of authorization claims for treatment facilities
• Geographic information layers (orthophotos, Regional Technical Map, Digital Terrain Model, accessibility and road graphs, administrative boundaries, land use map, land cadastre, river basins, hydrographic network., etc.)
• Agriculture Census (ISTAT)

At the present time, there is no procedure that can integrate the information in the databases mentioned, the content analysis of the information also showed that in spite of similar levels of information processed by different sources, the methods of information building in them contained may be substantially different and so, considerably differentiate the significance of the results of calculations performed.

For example, we show the different meanings that can have the variable livestock consistency: in the “Nitrate Communication” archives, data refers to the annual average number of livestock, in the BDR is related to the potential of farming (a given average number would be obtainable only in cattle), in the ISTAT census refers to the heads present at the time of survey, therefore, the three values for the same livestock breeding or territory may be substantially different, and as a consequence the estimated production of nitrogen resulting there from. Given this situation, it was decided to refer, wherever possible, to data that better reflects the actual situation and assess the impacts in terms of manure management, or the average number over the year, however, this is only available for the production realities above the thresholds of production and use of manure for which Regional legislation provides a compulsory communication. In any case, we tried to bridge the

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1 For a better understanding of the contents of the archives mentioned, here are the details of administrative acts of institution.
information gap by considering, after the identification of farms excluded from the “Nitrates Communication”, potential consistency data in the BDR, while data from ISTAT, official but not updated, is always considered as reference but not used for the indicators building.

Similar considerations, after all, can be made for the other parameters considered (land areas, cultivated crops etc.), for that, the Data Mart building is based on a series of very detailed considerations to make available the more appropriate information to the representation of reality, always taking into account the purpose of monitoring the local and territorial situation and sustaining decision-making.

Results and discussion

The decision to use the administrative databases for monitoring purposes has implications that can be summarized as follows:

Conveniences:

• It avoids the need to carry out a statistical survey sample, which would be static, expensive and less precise.
• We can get detailed and updated data: the rate at which farms are related with the public administration applications for subsidies, authorizations or compulsory communications means that records from administrative archives are systematically and promptly updated with very thorough detail; in contrast, the official statistics in agriculture, derived from the ISTAT census, have an annual update only on a provincial basis. Also sometimes, the methodology used for data processing does not reflect precisely the local territorial realities.
• The plurality of sources considered allows to overcome with uncertainty regarding the shortcomings of individual archives.

Inconveniences:

• For the analysis of data, it is necessary, first, a precise information note to whom concerned in which should be listed the terms and purposes of data collected, in that information note is indicated that the use of data should be also for statistical and monitoring purposes, but in any case the data treatment have to ensure the protection of personal data of the concerned.
• The available data are often very detailed, however, they are affected by the purpose for which they were collected: to simplify the compliance imposed to citizens, sometimes are present aggregated information that prevent the performance of calculations at a desired level of disaggregation (eg. Livestock consistency collected per business unit, which may include more livestock farms), other times the detail is very meticulous but aimed at the individual case and hardly re-aggregable into categories useful for monitoring (eg. encoding cultures of holding file).
• Furthermore, data are not always complete or does not relate to all the subjects. (eg. the “Nitrates Communication” is only of interest of companies/farms above a certain level of production or use of animal manure).

We tried to give a solution to these problems through comparison and integration of multiple archives, according to a hierarchy of quality and reliability of information, without excluding the integration (with levels of information always distinguishable) of the shortcomings coming from detailed and updated archives with more “generic” but complete data.

We found that only a deep understanding and analysis of the starting archives allows for reliable data and monitoring indicators: the “spot drawing” administrative records rarely give reliable results.

In general, difficulties were found, even known before based on previous experiences, to combine and integrate data from different archives, since information is often managed with identifying, varying and less compatible rules, codes and keys.

Conclusion

The operational activity of Action 1 of “RicuCaReflui” project is realized in several stages:
1. Identification and analysis of information;
2. Definition of a set of functional indicators necessary for the understanding of ongoing;
3. Implementation of a Data Mart that allows the integration, storage and consultation of information;
At present the task 1) was completed, and we are nearing the completion of stages 2) and 3). Activity 4) provides for representation in a GIS environment, already operating in the Region, of the results of activity 2) and 3).

When developing the project, we tried to give solution to the problem of uniformity lack of available data through the comparison and integration among multiple archives in accordance with a hierarchy of quality and reliability of information, without excluding the integration (with levels of information always distinguishable) of the shortcomings of the more detailed and updated archives with more “generic” but exhaustive data.

The expected outcome of Action 1 of RiduCaReflui project will be dynamic tabular and cartographic reporting system, capable of subsequent updates and optimizations when there will be significant development of the quality of the available archives.

Experience suggests, even in order to optimize investments, to pay the greatest attention, at planning level of information systems for administrative management, to the organization of archives in the collection of information that will be used for data statistical analysis and monitoring, an attention that seems not yet sufficiently widespread.

To this end, desirable common guidelines are needed to ensure the integrability of the different archives.

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**Literature cited**


Identification and evaluation of technical solutions for the rationalization of the logistics of animal waste

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Abstract
The Action 3 of the Project “RiduCaReflui” is aimed at the study of possible logistical solutions for the animal waste in input and in output from the treatment plant up to the in field distribution. The purpose is to plan and propose a regional logistics system for managing the movement and to identify the technical solutions whose adoption is recommended for a future implementation of animal waste management in the entire area of the Venetian basin lagoon watershed.

Keywords
Logistics, animal waste, field distribution, plant localization, traceability.

Introduction
Logistics in the transport of biomass plays an important role in the competitiveness of agriculture and in the management of livestock effluents, determining the sustainability of their use. Logistics is traditionally regarded as a set of activities related to the materials, products and information flow both within a single company and among companies (production), suppliers (production inputs) and customers (production outputs). The investigations are aimed to: the optimization of transports and storages (intermediate and final), the improvement of the traceability system, the implementation of computerized systems for the monitoring of vehicles and products flows. The optimization of logistics must be addressed to two integrated goals: maximizing the efficiency and minimizing the environmental impacts.

Results
Location of treatment plants
The geo-location problems concern the geographical location of a plant which there are matter flows in transit to and from other sites, where the material is produced, or used, or allocated (even in a form different to the produced one).

Figure 1 – Scheme of a generic problem of geo-location on a Cartesian plane (P = plant; So = Source; Si = sink), the arrows indicate flows of matter (solid line = conferring to the plant, dashed line = distribution from the plant).
The problem of the optimal location of treatment plants has been tackled step by step and with an increasing complexity:

- Defining a mathematical algorithm for finding a candidate position for the placement of the plant;
- Defining the objective function in a problem of logistics, starting from a distances-based formulation up to another form which can account the costs;
- Assigning different weights to the different “sources” and “sinks”, according to the amount of material moved from and to them respectively;
- Defining an approach which considers the existing road network (including also the country roads) and therefore which can take into account the actual routes that the transports must necessarily follow, rather than the distances computed along straight lines.

Transports
Another point of intervention concerns transports, by making a reasoned choice of the type of the cargo handling system and a rational dimensioning of it.

In general, the transport systems for livestock wastes can be:

- **Movable**, self-propelled (trucks of the “tank lorry” type) or non self-propelled (barrelled-type trailers, to be attached to a tractor), both having the payload volume configured as a cistern;
- **Fixed** (a network of pipelines which branches out of the conferring centre).

Among all the parameters useful for dimensioning a transport system and in the subsequent calculations of monetary advantage, the main one is the **Transport Momentum**, which is obtained by multiplying: (1) the average mass of cargo transported in a reference period (e.g. one year) (2) the average distance of transport. The transport momentum is related to the power required to the load travel, both for movable systems and for fixed installations.

Among the movable non-self-propelled systems (typically: barrelled trailers hauled by tractors, the most popular and versatile solution), a possible improvement is the use of tractors equipped with CVT transmission of the “power-split” hydro-mechanical type. These tractors are characterized by being able to run the engine at a nearly constant rotational speed, corresponding to the maximum engine torque (typically 1400 ÷ 1800 rpm), regardless of the vehicle speed. Only taking into account this engine management logic, a fuel saving, quantifiable in 10% during displacements, would occur. Moreover, the CVT transmissions have a better overall performance coefficient than the more popular “full-powershift” drives (equipped with always-engaged gears and electro-hydraulic clutches); the difference can be more than 20%, depending on the architecture chosen by the vehicle manufacturer.

Distribution technologies
The main objective of distribution must be the maximization of the interception of nutrients by the crop, thus reducing the amount remaining in the soil which is at risk of loss in the environment. This optimization requires (1) a precise timing in the distribution, in relation to the absorption rate of nutrients by the crops, and (2) a calibration of inputs, according to real needs. The best distribution techniques, which maximize the fertilizing capacity and control the processes of ammonia volatilization and nitrate leaching, are those that limit the exposure time and the contact surfaces between the slurry and the atmosphere.

The choice must follow different approaches related to the presence or not of crops during the application (grass or covered soil rather than bare soil). The best solution is a machine that can operate in both modes. This implies specific requirements in machines design, such as: a reduced mass and required power, a wide free span, ease of handling, precision in dosing, cheapness. Some prototypes are planned to be built in the Project.

Experimental tests allowed to verify that the surface burial reduces the losses of ammonia up to 80 ÷ 90%, not being too much influenced by climatic factors and allowing an increase in the quantity of products which can be distributed, thanks to the greater working depth and section. Even if utensils with large sweeps (“goose-foot” like) require more power than straight shank at the same working depths, they can operate at shorter depths and provide a better coverage of the slurry.

Traceability
The traceability of the chain of waste handling and distribution can be achieved within an agro-zootecchnical farm by using a system able to collect and record data about the handled quantities, the taken paths and the handling time. All the collected data must be stored at the offices of the equipment manager, at the disposal of the Supervisory Authority.

The practical implementation of this system is accomplished by installing some systems on the transports: some sensors (to estimate the quantities transported and the content of nutrients), an interface with CAN BUS - ISO BUS (to obtain data about the engine), a data acquisition unit (capable of collecting analogical and digital data from the different sensors and sending them to the Central Unit), the Central Unit (for the general management of the whole system, equipped with: buffer...
memory, autonomous power supply, SIM card, interface with the electrical supply of the tractor, a GNSS antenna (for tracing the position and the speed of the vehicle), a GPRS antenna (for data transmission).

For all those transports consisting of two basic units, the tractor (to provide the necessary power for traction) and the trailer (for the cargo transportation), the suggested architecture for a traceability system is the "Implement oriented" type, according to which the main electronic components are positioned on the implement (barrelled trailer). This system does not require any adjustment or installation involving the tractor, making possible the use of many tractors with the same trailer or the use of a tractor not of property (e.g. contractor). The electrical supply is provided through the cable which is normally used to connect the lighting equipment of the implement. There is also a second cable with the tractor used to acquire signals from the CAN BUS - ISO BUS.

The detection of the effluents chemical composition should be performed with probes that measure the variation of electrical conductivity and whose the electrodes are shaped like a "Jack" connector: in fact, the concentration of the cations NH$_4^+$ and K$^+$ is significantly correlated with the electrical conductivity (the linear correlation between NH$_4^+$ concentration and the electrical conductivity explains more than 82% of the variance within the various types of slurry). The advantages in the use of these sensors are numerous: ease of installation and maintenance, robustness and reliability, measurement speed, ease of use, complete automation, use in direct immersion in the slurry, no reagent required and no generation of toxic substances.

Figure 2 – Different components of a traceability system installed on a tanker trailer.

**Conclusion**

**Future works**

- Validation of the geo-location algorithm on a case study;
- Assessment of the environmental impedance of possible transport systems with regard to the air quality;
- Study of the environmental impacts (leaching of nitrate and release of ammonia) associated with the agronomical use of animal waste, keeping into account the timing and the pedoclimatic situation of a case study, extendible to the Veneto Region;
- Testing of the traceability system.
Feasibility study about the treatment of animal manure in abandoned wastewater treatment plants

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Abstract
Identification and assessment of the technical and economical viability of future manure treatment centers located in the western area of Treviso province, coming from the conversion of wastewater treatment plants that are going to be abandoned, goes through the evaluation of appropriate technology that maximizes the efficiency of solid-liquid separation, both in terms of total and volatile solids, both with regard to major nutrients, nitrogen and phosphorus. Five types of livestock have been identified from which slurry samples have to be collected for characterization and separation trials: dairy cattle, veal calves, bullocks, breeding and fattening pigs. In the first phase two samples of manures with very different contents of dry matter were collected (veal calves with 0.7% dry matter, dairy cattle with 8.3%). Samples are filtered through 0.1 mm mesh sieve for the separation of settleable solids (φ>0.1 mm) and then centrifuged at 4,000 rpm for 15 minutes for the separation of suspended solids (0.1<φ<0.01 mm). Nitrogen and phosphorus in the more diluted slurry are fully associated with the finer or soluble fraction, while in the denser slurry 40% nitrogen and 76% of the phosphorus are contained in the settling and suspended (<0.1 mm) fraction. The results for the liquid manure of dairy cattle are in line with the best separation efficiency data reported in literature. The solid-liquid separation treatment by centrifugation seems to be that which may allow a first substantial nitrogen and phosphorus reduction in slurry, which could be further increased with the use of flocculating agents. The treatment achieves maximum separation efficiency when dry matter content of fresh manure is higher and therefore it suits more for livestock with less use of washing water. It can not be usefully applied to veal calves manure in which nutrients are present in soluble form and therefore difficult to separate.

Keywords
Abandoned wastewater treatment plants, solid-liquid separation treatment, nitrogen removal, discharge into sewer

Introduction
In the northern district of Castelfranco Veneto (Province of Treviso) the potential disposal of manure on agricultural land are now severely limited, both in the presence of intensive farms for which the flow of waste products greatly exceeds the loads agronomically sustainable, both for the potential consequences of this practice, especially when not managed optimally, for surface and groundwater quality. This particularly regards the municipality areas of Asolo, Fonte, Paderno del Grappa, Maser, Altivole, Loria, S. Zenone degli Ezzelini, Riese Pio X, Castello di Godego, Crespano del Grappa, where livestock activities are very common and where nitrate concentrations among the highest of all the Province of Treviso are found in groundwater. In this area is already operational the connection of sewer cleaners among the various municipalities in the direction of the Salvatronda Castelfranco WTP, which should become next years the only centralized wastewater treatment plant. There are already plans to extend the sewer system also to the communes of Castelcucco, Borso del Grappa, Monfumo, Mussolente, Castelfranco Veneto. It should be noted that many livestock, for the particular pedological and hydrogeological characteristics of the area, saw significantly reduced the possibility of agricultural use of manures with the designation of nitrate vulnerable zones by the Region. The implementation of an integrated manure management between livestock, farms and sewage depuration service could be an effective solution to these problems at relatively low cost. The available data on the number of animals reared in the 15 municipalities in the area show mainly pig farms (2,800 sows and 27,000 fattening heads) and cattle (12,000 cows, 47,000 bullocks, 2,200 weaning and 43,500 veal calves). The total nitrogen load livestock (Table 1), calculated on the basis of the tables contained in the Ministerial Decree 04.07.2006, amounted to 2,927 tonnes, for a unit load of about 139 kg/ha; also considering that, by excluding cattle milk, all other categories will most likely produce slurry, a volume greater than 2500 cubic meters of sewage per day is produced.
Table 1 – Estimated nitrogen load per unit area produced by livestock (livestock N), distributed with the fertilizer (mineral N) and used by crops (uptake)

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Crops surface (ha)</th>
<th>mineral N (kg/ha)</th>
<th>livestock N (kg/ha)</th>
<th>total N (kg/ha)</th>
<th>N uptake (kg/ha)</th>
<th>ΔN (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altivole</td>
<td>2534</td>
<td>164.0</td>
<td>171.1</td>
<td>335.1</td>
<td>124.5</td>
<td>210.5</td>
</tr>
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<td>Asolo</td>
<td>1760</td>
<td>173.2</td>
<td>121.7</td>
<td>295.0</td>
<td>147.4</td>
<td>147.5</td>
</tr>
<tr>
<td>Borso del G.</td>
<td>1089</td>
<td>96.3</td>
<td>58.2</td>
<td>154.6</td>
<td>128.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Castelcucco</td>
<td>438</td>
<td>147.8</td>
<td>231.5</td>
<td>379.3</td>
<td>176.7</td>
<td>202.6</td>
</tr>
<tr>
<td>Castelfranco V.</td>
<td>2550</td>
<td>215.3</td>
<td>134.4</td>
<td>349.7</td>
<td>143.0</td>
<td>206.7</td>
</tr>
<tr>
<td>Castello di G.</td>
<td>1251</td>
<td>218.9</td>
<td>104.0</td>
<td>322.9</td>
<td>157.0</td>
<td>165.9</td>
</tr>
<tr>
<td>Crespano del G.</td>
<td>1117</td>
<td>94.2</td>
<td>181.2</td>
<td>275.5</td>
<td>112.8</td>
<td>162.6</td>
</tr>
<tr>
<td>Fonte</td>
<td>850</td>
<td>188.5</td>
<td>211.2</td>
<td>399.8</td>
<td>175.1</td>
<td>224.6</td>
</tr>
<tr>
<td>Loria</td>
<td>1595</td>
<td>231.6</td>
<td>221.6</td>
<td>453.3</td>
<td>154.8</td>
<td>298.4</td>
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<tr>
<td>Maser</td>
<td>1391</td>
<td>164.8</td>
<td>106.6</td>
<td>271.4</td>
<td>134.2</td>
<td>137.1</td>
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<tr>
<td>Montefumo</td>
<td>525</td>
<td>98.5</td>
<td>107.8</td>
<td>206.4</td>
<td>133.2</td>
<td>73.2</td>
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<tr>
<td>Mussolette</td>
<td>1126</td>
<td>149.7</td>
<td>65.4</td>
<td>215.2</td>
<td>157.0</td>
<td>58.1</td>
</tr>
<tr>
<td>Paderno del G.</td>
<td>457</td>
<td>122.9</td>
<td>102.2</td>
<td>225.1</td>
<td>140.3</td>
<td>84.8</td>
</tr>
<tr>
<td>Riese Pio X</td>
<td>3187</td>
<td>225.1</td>
<td>140.6</td>
<td>365.8</td>
<td>195.2</td>
<td>170.6</td>
</tr>
<tr>
<td>San Zenone degli E.</td>
<td>1191</td>
<td>203.0</td>
<td>126.7</td>
<td>329.7</td>
<td>180.1</td>
<td>149.5</td>
</tr>
<tr>
<td><strong>TOTALE</strong></td>
<td><strong>21059</strong></td>
<td><strong>166.3</strong></td>
<td><strong>139.0</strong></td>
<td><strong>305.3</strong></td>
<td><strong>150.7</strong></td>
<td><strong>154.6</strong></td>
</tr>
</tbody>
</table>

The calculation of nitrogen loads from agriculture and livestock evidences that the nitrogen crop needs are entirely covered by the use of fertilizers purchased (ISTAT), and then there are currently substantial surplus of nitrogen, in some municipalities exceeding 200 kg/ha/year.

The action 4 of project “Riducareflui” aims to identify the optimum operating conditions and assess the economic viability of future manure treatment centers located in the area, converting the wastewater treatment plants that have abandoned, or that will be shortly after the connection of all municipal sewage to the consortium plant in the city of Castelfranco. These centers should be equipped with a reception phase of the sewage, by species, consisting of a screening with storage, mechanical separation of coarse and fine solids and a clarified liquid storage associated with a biological treatment, nitrification and denitrification.

The first plant development therefore requires the identification of appropriate technology that maximizes the efficiency of solid-liquid separation, both in terms of total and volatile solids, both with regard to major nutrients, nitrogen and phosphorus.

Bibliography can be found in very different directions about the effectiveness of different solid-liquid separation technologies for better management of livestock slurries.

In Table 2 the results of some of the most significant experiences in this respect area summarized; they concern both pigs and cattle slurry, predominantly mechanical separation systems (horizontal or rotary screens of various types) or centrifugation. The data are very different between authors as we can conclude that the optimal solution must be developed on a case by case basis, depending on the type of slurry to be treated and taking into consideration available technology.

The use of flocculant agents give always very positive results and costs, when quantified, rather than low.

Another constant evidence is that removal efficiency is directly proportional to dry matter content of slurry.

**Material and methods**

The proposed action consists of two phases: the laboratory tests (phase 1) and tests in pilot plant that has to be positioned on the at a sewage treatment plant (phase 2), during which some solid-liquid separation technologies will be tested in order to limit the amount of clarified slurry to be treated, and sustainability of technical refinement of the purification process (bioreactor configuration in SBR and/or MBR) will be verified.

The plant identified for carrying out the tests required to verify the technical feasibility of the route described above, is in the Municipality of Fonte. The Municipality council has agreed to make available the plant while placing some constraints (excluding pig slurry, completion of testing activities within 12 months).
Table 2 – Removal efficiency of solids and nutrients (%) from pig slurry and cattle following treatment of solid-liquid separation reported by various authors (see literature cited for references).

<table>
<thead>
<tr>
<th>Author</th>
<th>Manure</th>
<th>% DM</th>
<th>Technol.</th>
<th>Floc</th>
<th>TS</th>
<th>VS</th>
<th>NT</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balsari 2006</td>
<td>Pig</td>
<td>5.3</td>
<td>Centrifuge no</td>
<td>30.6-69.7</td>
<td>--</td>
<td>8.9-25.7</td>
<td>59.6-84.0</td>
<td></td>
</tr>
<tr>
<td>Balsari 2006</td>
<td>Pig</td>
<td>5.3</td>
<td>Screen no</td>
<td>15.5</td>
<td>16.9</td>
<td>15.5</td>
<td>16.9</td>
<td>15.5</td>
</tr>
<tr>
<td>Møller 2002</td>
<td>Pig</td>
<td>5.3</td>
<td>Screen yes</td>
<td>95</td>
<td>95</td>
<td>35</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Westerman 2000</td>
<td>Pig</td>
<td>0.8</td>
<td>Screen yes</td>
<td>34</td>
<td>50</td>
<td>22</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Balsari 2006</td>
<td>Cattle</td>
<td>6.4</td>
<td>Screen no</td>
<td>27.6-77.8</td>
<td>--</td>
<td>10.4-36.5</td>
<td>32.8-73.7</td>
<td></td>
</tr>
<tr>
<td>Møller 2002</td>
<td>Cattle</td>
<td>6.4</td>
<td>Screen no</td>
<td>54.1-69.1</td>
<td>--</td>
<td>20.3-29.2</td>
<td>75.9-93.8</td>
<td></td>
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<tr>
<td>Castrillon 2009</td>
<td>Cattle</td>
<td>4.1</td>
<td>Centrifuge no</td>
<td>35.2</td>
<td>41</td>
<td>20</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Chastain 2001</td>
<td>Cattle</td>
<td>6.4</td>
<td>Centrifuge no</td>
<td>54.1-69.1</td>
<td>--</td>
<td>20.3-29.2</td>
<td>75.9-93.8</td>
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</tr>
<tr>
<td>Chastain 2001</td>
<td>Cattle</td>
<td>6.4</td>
<td>Centrifuge no</td>
<td>35.2</td>
<td>41</td>
<td>20</td>
<td>75</td>
<td></td>
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<tr>
<td>Garcia 2009</td>
<td>Cattle</td>
<td>6.4</td>
<td>Screen yes</td>
<td>95.3</td>
<td>92.3</td>
<td>86.0</td>
<td>61.9</td>
<td></td>
</tr>
</tbody>
</table>

Laboratory Tests

Five types of livestock farms have been identified from which samples have to be collected for characterization and separation trials: dairy cattle, veal calves, bullocks, breeding and fattening pigs.

In the first phase of the trial two samples of manures with very different contents of dry matter were collected: the first at the breeding of veal calves with 0.7% dry matter, the second in the breeding of dairy cattle with 8.3% dry matter. The sampling was performed taking many primary samples from different depths of the basins where fresh slurry is delivered and then combining them to form the sample for analysis.

To verify the distribution of nutrients between the different fractions, several methods of separation of settleable solids (particle diameter > 0.1 mm), suspended (diameter <0.1 and > 0.01 mm) and colloidal (diameter <0.01 mm) have been tested; the protocol has been defined splitting the sample into different fractions before their characterization. It consists of two steps:
- filtration through 0.1 mm mesh sieve for the separation of settleable solids;
- centrifugation at 4,000 rpm for 15 minutes for the separation of suspended solids.

Determination of total solids (ST), volatile solids (SV), Kjeldahl (NT) and ammonium nitrogen, COD, total and soluble phosphorus, pH and conductivity were performed.

The tests should be completed analysing the remaining three types of manure identified and subsequently extending to the liquid fraction resulting after submitting the effluent to treatment with agents flocculants (polyelectrolytes) and centrifugation to assess the efficiency of solid-liquid separation of organic components, nitrogen and phosphorus induced by each substance at different concentrations.

In order to increase the possible transfer of the pollutant load (and especially the nitrogen component) to the solid fraction tests of centrifuged slurry clarification through jar tests are planned, to evaluate the effectiveness of some biopolymers in precipitation of protein that may be present in colloidal and soluble fraction.

Pilot plant tests

A horizontal 9 kW decanter is hired, complete with feed pump with variable flow, auger and sludge disposal electrical control panel, in order to carry out tests of solid-liquid separation both on the first solid fraction and on which may separate in a second step through a process of flocculation through biopolymers addition (removal efficiency and reaction times will be tested). The clarified is then sent to a pilot plant for biological treatment of wastewater mode SBR/MBR, with flow rates of about 100 litres/h.

Tests are scheduled for total oxidation of organic matter and ammonia with monitoring of all operating and process parameters to allow technical and economic evaluation on the process (cost of plant construction and management thereof) to plant scale in relation to different levels of reduction of COD, TSS, Nitrogen and Phosphorus. The plant has the chance to record consumption of electricity, the dissolved oxygen content in oxidation tank, the flow treated air supply and the production of surplus activated sludge.
Results and discussion

The results from the characterization of the two analyzed samples are presented in Table 3.

Table 3 – Physical-chemical characteristics of two samples of fresh manure and its separated fractions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>u.m.</th>
<th>Veals</th>
<th>Dairy Cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manure</td>
<td>&lt;0.1 mm</td>
<td>&lt;0.01 mm</td>
</tr>
<tr>
<td>ST</td>
<td>%</td>
<td>0.7</td>
<td>0.68</td>
</tr>
<tr>
<td>SV</td>
<td>%</td>
<td>37.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Total P mg/l</td>
<td>191</td>
<td>188</td>
<td>190</td>
</tr>
<tr>
<td>Soluble P mg/l</td>
<td>---</td>
<td>170</td>
<td>177</td>
</tr>
<tr>
<td>COD g/l</td>
<td>2.80</td>
<td>2.57</td>
<td>1.81</td>
</tr>
<tr>
<td>Total Kjeldahl N mg/l</td>
<td>1479</td>
<td>1348</td>
<td>1430</td>
</tr>
<tr>
<td>Ammonium N mg/l</td>
<td>120</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>pH</td>
<td>8.19</td>
<td>8.34</td>
<td>---</td>
</tr>
<tr>
<td>Conductivity mS/cm</td>
<td>1.73</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Data show that nitrogen and phosphorus in the more diluted slurry are fully associated with the finer or soluble fraction, while in the denser slurry 40% nitrogen and 76% of the phosphorus are contained in the settling and suspended (<0.1 mm) fraction, that can be separated by centrifugation. The results for the liquid manure of dairy cattle are in line with the best separation efficiency data reported in literature (Table 2); it is to verify whether the same occurs for the samples of slurry from meat cattle and pigs and if these efficiencies are improved by adding flocculating agents prior to separation treatment.

Conclusion

The solid-liquid separation treatment by centrifugation seems to be that which may allow a first substantial nitrogen and phosphorus reduction in slurry, which could be further increased with the use of flocculating agents. The treatment achieves maximum separation efficiency when dry matter content of fresh manure is higher and therefore it suits more for livestock with less use of washing water. It can not be usefully applied to veal calves manure in which nutrients are present in soluble form and therefore difficult to separate.

Literature cited


Technologies for the treatment of digestate: biological treatment, drying, vacuum concentration, ultra-filtration and reverse osmosis. Feasibility and environmental sustainability

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Abstract
As a part of a comprehensive Research Project financed by Veneto Agricoltura and the Veneto Region, Italy, the most relevant technologies for the management of digestate and farming effluents are subject to intensive monitoring, with the main objective of evaluating the efficiency of each process, also in the optic of complying with the Nitrates Directive, which limits the quantity of nitrogen that could be spread on agricultural land.

The main technologies that are under monitoring/set-up are represented by nitrification-denitrification, liquid/solid separation, membrane filtration (ultra-filtration and reverse osmosis), digestate drying and vacuum concentration.

The tests are performed in Italy, and abroad, analysing the input and output flows, in terms of quality and quantity, with particular attention to the destiny of N and P. The present work aims to present some of the results of this project.

Keywords
Manure, anaerobic digestion, biogas, digestate, osmosis, ultra-filtration, concentration, nitrification denitrification, drying.

Introduction
The present study is a part of a comprehensive Research Project financed by Veneto Agricoltura and the Veneto Region, with the main objective of evaluating the most promising processes for the treatment of digestate and farming effluents, in the optic of complying with the Nitrates Directive.

Anaerobic digestion of organic waste and/or livestock manure represents a great opportunity, not only for the revenues related to the production of energy from renewable sources, but also from social and environmental points of view. Nitrogen content of digestate, anyway, is not affected by the process in terms of quantity: where surplus nitrogen is a problem, dedicated solutions must be implemented.

Possible solutions belong to two different general approaches, the “destructive” and the “conservative” approaches. The so called “destructive approach” consists on the implementation of treatments for the removal of nitrogen from digestate and its emission into the atmosphere in the form of molecular nitrogen (N2), which is the main component of the atmosphere itself. This method is essentially represented by biological processes such as nitrification-denitrification.

The treatment of digestate in order to produce effluents with high fertilizing potential is the core of the “conservative approach”: with these systems a portion of input nitrogen is diverted into different fractions, easier to be managed and with higher concentration of nutrients, if compared to raw digestate.

Some of the most interesting “conservative” options for the management of digestate, besides simple separation, are represented by processes such as drying, vacuum concentration/evaporation, ultra-filtration and reverse osmosis. These represent extremely new solutions for the treatment of digestate or manure.

Material and Methods
Several full scale plants and, where not available, pilot-scale treatment plants are under monitoring/set-up in frame of the project, in Italy and abroad.

The general approach that has been chosen is represented by a 360 degree testing of the plants, with the evaluation of the performance, characterization of input and output streams of each process, determination of mass flows, nutrients flows and energy consumption, and finally, with the monitoring of the emissions, where applicable. Possible improvements in the set-up of each process are also evaluated.
Results and Discussion

Digestate Drying

The first full-scale plant realized in Italy, equipped with exhaust air treatment, was subject to monitoring. Digestate drying is performed by means of a dedicated equipment featuring perforated metal belts, on which digestate is spread, crossed by forced airflow. In order to improve the evaporation rate, ambient air is heated by water/air exchangers and mixed with exhaust gases from CHP units. The exhaust air from the drying beds is subject to water/acid scrubbing to control the emissions, with consequent production of ammonium sulphate. The system is enclosed and maintained in negative pressure by means of the operation of fans mounted on the chimneys. The drying capacity of a full scale plant is determined mainly by the availability of thermal energy, which can be recovered both from exhaust air from and from hot water from CHP units. The throughput of the system, in terms of dry product, is variable: the monitored drying equipment is capable of processing an average of 47%, on weight basis, of digestate produced by the biogas plant. In general, by processing 47% of digestate, the plant diverts from the main stream also 47% of nitrogen, that is contained both in dry digestate and in ammonium sulphate. These materials are produced in small quantities, compared to digestate, about 4% for dry digestate and 1% for ammonium sulphate, and are characterised by high nutrients content.

The dried product is characterised by total solids content of about 90%, with a total nitrogen content of about 30 g/kg. Ammonium sulphate is produced in a 35% solution with a pH that is around 3-4, and with an ammonium concentration that can reach even 100 gNH₃/kg.

The effectiveness of the exhaust air treating process is a key factor in this process. The first results show that an effective removal of ammonia can be achieved, but a proper setting of the system is essential.

Vacuum Concentration

The vacuum evaporation process consists in the creation of negative-pressure conditions in a dedicated equipment, maintaining temperature levels comparable to boiling conditions at that pressure. In such conditions water evaporation takes place; evaporated water, then, is condensed and collected in the distillate tank. Tests were conducted on a two stage pilot-scale system. The vacuum concentration process determines a significant reduction of the volume of digestate: in terms of mass, the first stage determines a reduction of 80% compared to the input (concentrate represents 20% of input); the final concentrated output represents only 6% of initial product. With a proper pH correction, almost 97% of nitrogen remains in the concentrated fraction. This product is characterised by very high concentration of ammonia, about 40'000 mg N-NH₃+/kg compared to 2'450 mg N-NH₃+/kg of filtered digestate, and also of total nitrogen, 55'000 mg TKN/kg compared to 3'377 mg TKN/kg of filtered digestate. The concentrated output from the first stage is still liquid, with a total solids content of about 15,0%, from 3,3% of filtered digestate. The output of the second stage of the treatment is solid, with a total solids content of 63,0%. Distilled water, instead, represents 94% of input weight and contains about 3% of nitrogen. This fraction
could be purified to achieve quality levels compliant with discharge limits, but, most likely, could be simply used as dilution water for internal purposes.

**Figure 2** – Mass and nitrogen balance for the vacuum concentration process (left). Detail of a pilot-scale vacuum concentration plant (right).

Ultra-filtration and reverse osmosis
Membrane treatment, i.e. ultra-filtration and reverse osmosis, represents a high-tech system derived from other sectors, including industrial applications and the production of drinking water (US EPA, 2005). An advanced separation system featuring screw-press separation (SEP), decanter separation (DEC), ultra-filtration (UF) and reverse osmosis (RO) was monitored in Germany.

**Figure 3** – Diagrams of mass and nitrogen balances of the entire process (left). Photos of the main treatment stages (right) including screw-press separation (a), decanter separation (b), ultra-filtration (c) and reverse osmosis (d).

The entire multi-stage treatment plant produced, on weight basis, in relation to digestate, 48% of filtered water, 35% of solids and 17% of concentrate. The solids from the two separation stages and the concentrate from RO represent the outputs with a fertilizing capacity. Permeate represents a “clean” output, with COD lower than 15 mg/l, starting from 55’000 mg/l for digestate, a concentration of ammonia of 0.025 mg/l starting from initial 2’280 mg/l. The achievement of quality levels compliant with discharge limits is potentially feasible but probably it is more realistic to use this fraction as dilution water for internal purposes.
As far as nitrogen is concerned, the first stage (screw-press) showed a limited efficiency, by removing with the solids 11% of input nitrogen. The second separation stage (decanter), instead, showed higher performance, with a removal of 61% of initial nitrogen. The remaining amount of nitrogen was removed by the advanced filtering system (UF+RO): the concentrated fraction from RO contains 28% of initial nitrogen. Nitrogen in the permeate resulted irrelevant.

Conclusion

Destructive systems, such as nitrification-denitrification determine the removal of significant percentages of input nitrogen, such as 70% and even more, and its emission into the atmosphere as N2, main component of air, with no significant impact. As a result, even if no volume reduction is obtained, reduction of nitrogen load is achieved. Conservative systems, instead, are all characterized by a valorisation of digestate, obtained by means of a reduction of volume: typically lower quantities of high nutrient products represent the outputs of such processes. Many of the outputs of these systems, such as dry digestate and ammonium sulphate from drying systems, concentrate for vacuum evaporation, solid fractions from separation, or such as the concentrate from membrane treatment, are characterised by significant content of nitrogen. This means a significant potential for agricultural utilization of these products, but, also, that where an effective reduction of nitrogen load on agricultural land has to be achieved a portion of these products should be transported elsewhere or, eventually, sold. In Italy, at the moment, the potential market for this products is still uncertain.

It is not possible to define a general solution, each case is characterised by some peculiarities and a dedicated solution should be studied.

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Technologies for animal manure management: treatment of poultry manure to obtain better quality productsy

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Abstract
This work presents the initial results of a monitoring activity on poultry litter stored in small farm piles. The activity is part of a wider project that has the aim of improving poultry litter management for use as a raw material for the production of organic fertiliser.

The practical activity consists in monitoring the temperature in the pile during the whole storage period and in analysing samples of the material at the beginning and at the end of the storage period, in order to verify if it meets the limits in chemical and microbiological parameters set by the Italian law on fertilisers (Dleg 75/2010).

Initial results show that the material at the end of a three-month storage is compatible with its use as an organic fertiliser; the temperature in static-piles has a maximum value of around 55°C, while in piles turned monthly it exceeds 60°C.

Keywords
poultry litter; storage; organic fertiliser.

Introduction
Poultry production in Italy is concentrated in four regions: Veneto, Lombardia, Emilia-Romagna and Piemonte. Veneto is the main producer, having the 28% of the poultry heads bred in Italy (table 1). Here farms are concentrated in few areas (Verona, Vicenza, Padova and Treviso) and tend to be very intensive, without land ownership and feed coming mainly from outside (they are called “no-land” farms).

High livestock density in a restricted area results in a surplus of manure that can’t be spread on the field without exceeding the limits established by the Nitrate Directive (n. 676/91/CE). It has been calculated that in Veneto there is a surplus of nitrogen from poultry farming of about 12.600 tons/year.

Table 1 – poultry heads in Italy and Veneto (source: ISTAT 2000).

<table>
<thead>
<tr>
<th>poultry heads</th>
<th>%</th>
</tr>
</thead>
<tbody>
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<td>North</td>
<td>128.618.563</td>
</tr>
<tr>
<td>Centre</td>
<td>30.306.566</td>
</tr>
<tr>
<td>South</td>
<td>12.474.086</td>
</tr>
<tr>
<td>Italy</td>
<td>171.399.215</td>
</tr>
<tr>
<td>of which:</td>
<td></td>
</tr>
<tr>
<td>Veneto</td>
<td>47.983.231</td>
</tr>
<tr>
<td>of which:</td>
<td></td>
</tr>
<tr>
<td>Verona</td>
<td>20.555.231</td>
</tr>
<tr>
<td>Vicenza</td>
<td>8.701.776</td>
</tr>
<tr>
<td>Padova</td>
<td>7.761.066</td>
</tr>
<tr>
<td>Treviso</td>
<td>7.067.343</td>
</tr>
<tr>
<td>others (Ve, Ro, Bi)</td>
<td>3.897.815</td>
</tr>
</tbody>
</table>

The redistribution of poultry litter between areas with nutrient surplus and those with shortage is limited by transportation and spreading costs. Alternatives to land application are direct combustion and agronomical valorisation to produce organic fertilisers.

The latter enables recycling of the organic matter and nutrients in agriculture and their use as fertilisers in a wider area (through commercialisation), thereby making it possible to respect the Nitrate Directive (ND) and the Code of Good Agro-
nomical Practice (CBPA). However, there is a great competition in the market with chemical fertilisers that are cheaper and easier to use, and compost obtained from other materials, eg the organic fraction of urban wastes. This product is often of a worse quality but it is given free to farmers for use as soil amendment.

Direct combustion and agronomical valorisation are opposite but complementary, and they could coexist in the same area by offering a wide choice for poultry litter management.

The aim of the present study is to evaluate the technical-logistical requirements necessary for the creation of a product line connecting farmers (on their own or in partnership) to producers of organic fertilisers. Here, the diagram summarizing the steps of the chain of production “from litter to fertiliser” assumes that the farmer works on his own (no partnership between farmers):

<table>
<thead>
<tr>
<th>Place</th>
<th>Activity</th>
<th>Transport</th>
<th>fertiliser factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>farm</td>
<td>aerobic stabilisation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Such a management system allows farmers to respect the ND, the surplus nitrogen leaving the farm as fertiliser, and makes the disposal of the manure clear. This last aspect is very important in poultry farms, because till now, those who don’t have a dunghill are forced to get rid of the worn-out litter before the beginning of a new breeding cycle, even paying for the disposal.

There are also benefits for the producers, who are guaranteed a steady supply of the material, both in quantity and in quality.

Concerning the on-farm activities, the basic requirements are:
- the presence of a dunghill, where the litter is stored and where the aerobic stabilisation of the organic matter takes place;
- to respect of a reference document for the management of the material;
- a check of the material at the end of the storage period to be sure that it has the characteristics required for the transfert to the production site.

Other requirements are:
- the classification of the material that has to be translated from the farm to the production site, from the point of view of the law;
- minimum requirements of environmental compatibility for the activity that takes place in the farm.

Concerning the first aspect, the reference law is the Dleg n. 75/2010, on the production of fertilisers; we can cite also the L. n. 129 dated 13/08/2010, in which poultry litter is classified as a “byproduct” (and, consequently, no more as a waste) if it has to be used for energy production.

**Material and methods**

The purpose of the present activity is to verify if after a 90-day storage in a dunghill poultry litter achieves the standards required by the Dleg n. 75/10 necessary to be classified as a “fertiliser” (Table 2). Ninety days is the minimum period of storage required by DM n. 209/06 for poultry manure.

Monitoring is carried out on poultry litter from turkey and broiler farms (3 farms each) and on dried poultry manure from egg production farms (2 farms).

Worn-out litter is placed on pile into the dunghill that can be either covered or not. For this study we chose farms with dunghills having the basic requirements established by legislation (CBPA/IPPC).

If the pile is a turned one, the material is turned monthly and a tractor with a mechanical digger is used.

The temperature of the material is monitored continuously through micro-data loggers placed at different depths in the pile; the increase of temperature ensures the development of aerobic fermentations, responsible for the right stabilisation of the organic matter.

At the beginning and at the end of the storage period a sample of the material is taken in order to analyse the chemical-microbiological parameters listed in Table 2.
Table 2 – Requirements of the Dleg n. 75/10 to classify a product as a “fertiliser” and other parameters analysed in the trials.

<table>
<thead>
<tr>
<th>Parameters ex Dleg 75/10</th>
<th>Clostridium perfringens</th>
<th>SF</th>
<th>Microbiological</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salomonella</td>
<td>UFC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enterobacteriaceae</td>
<td>UFC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>max 2 samples /5 with CFU between 10 and 300</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 1,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 230</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 1,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norg+P2O5 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pb mg/kg</td>
<td>&lt; 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cd mg/kg</td>
<td>&lt; 1,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ni mg/kg</td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zn mg/kg</td>
<td>&lt; 500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu mg/kg</td>
<td>&lt; 230</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hg mg/kg</td>
<td>&lt; 1,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cr VI mg/kg</td>
<td>&lt; 0,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total solids (%)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ash (%)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N (%)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K2O (%)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Humic acids</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fulvic acids</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Respirometric Index</td>
<td>(%)</td>
<td></td>
</tr>
</tbody>
</table>

Results and discussion

The initial results of microbiological analyses show that the material at the end of the storage reaches the standards required by the Dleg n. 75/10. These results refer to samples of worn-out turkey litter stored from March to June in a static-pile in a non-covered dunghill.

The temperature trend shows that in a static-pile a temperature of about 55°C can be reached, no matter what type of manure (broiler, turkey or hen) or type of dunghill (covered or not) is used, while in turned piles higher temperatures can be reached – of over 60°C (Table 3).

Table 3 – Temperature values in pile on four trials.

<table>
<thead>
<tr>
<th>TRIAL</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>period</td>
<td>17/05-17/08</td>
<td>17/05-17/08</td>
<td>17/05-17/08</td>
<td>18/09-09+13/01/10</td>
</tr>
<tr>
<td>type</td>
<td>turkey</td>
<td>hen</td>
<td>Broiler</td>
<td>turkey</td>
</tr>
<tr>
<td>material</td>
<td>litter</td>
<td>Dried manure</td>
<td>litter</td>
<td>litter</td>
</tr>
<tr>
<td>turning</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>min °C</td>
<td>40,1</td>
<td>33,0</td>
<td>35,5</td>
<td>33</td>
</tr>
<tr>
<td>max °C</td>
<td>56,3</td>
<td>51,3</td>
<td>58,5</td>
<td>63,8</td>
</tr>
<tr>
<td>Medium °C</td>
<td>52,7</td>
<td>42,7</td>
<td>49,3</td>
<td>53,1</td>
</tr>
<tr>
<td>St Dev</td>
<td>2,95</td>
<td>4,51</td>
<td>5,60</td>
<td>6,31</td>
</tr>
</tbody>
</table>
Figure 1 – Trial A-trend of temperature collected by the data loggers placed in the pile at three different depths: A(middle), B(top), C(bottom).

Conclusion
With the purpose of increasing the commercial value of poultry manure, one way is to connect farmers to producers: the former are sure on being able to dispose of the manure, and the latter are guaranteed a steady supply of the material.
In order to achieve agronomical and hygienic standards for the use and the transport as fertilisers (set by the Italian law, Dleg n. 75/2010), the aerobic stabilisation of the litter has to be achieved.
With the present study a minimum processing of the poultry manure has been realised: the worn-out litter is stored in piles, either static or turned (monthly); initial results show the role of a three-month storage in dunghill for the stabilisation of the material both from the agronomical and hygienic points of view.

Acknowledgements
We acknowledge all the farmers who give hospitality to our trials in their farms.

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Legge 13 agosto 2010, n. 129 Conversione in legge del DI 8 luglio 2010, n. 105 recante misure urgenti in materia di energia e disposizioni per le energie rinnovabili.
Anaerobic digestion of livestock effluents: advantages and disadvantages, bottlenecks and future perspectives in the Veneto Region

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² Department of Environmental Sciences, University Ca’ Foscari of Venice

Abstract

In this paper the application of the anaerobic digestion of livestock effluents in some farm-plants of the Veneto Region is presented. It was found that manure was typical co-treated with energy corps (maize and triticale silage) and agro-waste to improve biogas yields, as usual in Europe. All the monitored reactors operated in mesophilic conditions (38-40°C) with organic loading rate of 2-3 kgVS/m³ per day and retention times greater than 42 days. When adopting the co-digestion option yields were in the range 0,5-0,6 m³ per kgVS fed. As high levels of ammonia nitrogen are reached in the liquid phase of the digestate, this was treated by an automatically controlled sequencing batch reactor for effective nitrogen removal. The anaerobic digestate of pig manure showed ammonia concentration of 1,5-2,0 gN-NH₄/L, bCOD:N < 1 and conductivity of 14-16 mS/cm, involving potential, but surmountable, difficulties for the bioprocesses.

Keywords

Anaerobic digestion, ammonia, biological nitrogen removal, biogas, livestock effluents

Introduction

Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits (production of renewable energy and reduction of greenhouse gas emissions as well as production of a digestate with good fertilizing attitude) and is an additional source of income for farmers (Amon et al., 2007). Beside cattle manure, energy crops are generally fed to the anaerobic reactors. Maize is the most dominating crop for biogas production: in fact more than 40 ton per hectare can be produced in Europe and its biogas yield is up to 0,35 m³CH₄ per kg VS (after silaging). Moreover, also other agro-waste and biowaste can be of interest because of their energy potential: e.g., slaughterhouse residues, molasses, vinasses, crops residues, food processing waste and kitchen waste among the others (Angelidaki and Ellegaard, 2003). According to this scenario, the anaerobic co-digestion process of livestock effluents and agricultural waste is widely applied in Europe: approximately 4000 farm-plants are operating in Germany (Weiland, 2010), 22 centralized plants and hundreds of farm-plants operate in Denmark (Angelidaki and Ellegaard, 2003) and other thousands in Austria (Lindorfer et al., 2007). Because of the favorable grants for the production of renewable energy, the application of this process in farms is now very appealing also in Italy and the number of farm-plants is growing very fast also in the Veneto Region: the number of requests for the construction of anaerobic reactors treating livestock effluents skyrocketed passing from 4 in 2007 to 13 in 2008 and 20 in 2009.

One problem related to intensified livestock production is the use of manure as organic fertilizer in relatively small areas: as a consequence, nitrogen is over-applied on soils and concentration up to 30-40 mgNO₃/L can be found in water bodies and groundwater (Bernet and Beline, 2009). Unfortunately, a typical drawback of AD is its capability of destroying proteins, determining “ammonification” then resulting in high ammonia levels in the digestate thus worsening the environmental problems. On the other hand, the high energy yields related to the anaerobic co-digestion of manure and energy corps or agro-waste open the possibility to the application of hi-tech processes for nitrogen control because of the good economic incomes. At present both chemico-physical and biological processes are applied for either nitrogen removal or recovery from digestate, but the cost/benefits framework is very heterogeneous and unclear (Bakx, 2010). Therefore, the definition of the best available techniques for the agricultural sector is definitely an open issue. Among the biological processes, the nitrite route could drastically reduce the operation and management cost, while potentially increase the gaseous emissions of nitrous oxides (Chen et al., 2009).

In this paper we give some insights about the application of the anaerobic digestion process for the treatment of livestock effluents and the nitrogen control in digestate management through biological processes in the Veneto Region.
Material and Methods

In this study six farm anaerobic digestion plants operating in the Veneto Region were considered. The energy yields and mass balances for total solids (TS), total volatile solids (TVS), organic matter (as COD) and nitrogen were determined considering several consecutive HRTs of the system. Trials on biological nitrogen removal were carried out treating the most crucial digestate, by an automatically controlled sequencing batch reactor (SBR). This came from the anaerobic digestion of pig manure, where the liquid digestate is periodically recycled to wash the floor of the pigsties, thus drastically increasing the salinity of the digestate. Besides the detailed analytical monitoring, the SBR was equipped with in-situ probes of DO, ORP, pH, conductivity, N-NH4 and N-NO3, so as to allow us to study and validate the best algorithms (coded in LabView 8.6) to monitor and control the bioprocesses. The automatic control was based on an algorithm designed by the authors. Differently from the traditional SBR timer-based, our control system operated the real-time data processing of time, DO, ORP, pH and conductivity. The structure according to five different branches allowed us the automatic control and optimization of: (a) blowers’ aeration; (b) dosage of the external carbon; (c) durations of the phases.

Results and discussion

As for the anaerobic digestion process, in the 6 cases study considered here, particular attention was dedicated to the different substrates fed to the AD reactors. Table 1 shows the feeding mix of the digestion plants: in 5 cases out of 6 the co-digestion approach was preferred. In particular, energy crops (maize and triticale silage) and agro-waste were fed to the reactors. In two cases (II and V) also glycerol originated as by-product from biodiesel production was fed to the reactors.

Table 1 – Feeding composition for the six farm anaerobic digestion plants considered in the study.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Piggery effluent</td>
</tr>
<tr>
<td>II</td>
<td>Piggery effluent Energy crops</td>
</tr>
<tr>
<td>III</td>
<td>Cow effluent Energy crops</td>
</tr>
<tr>
<td>IV</td>
<td>Poultry effluent Energy crops</td>
</tr>
<tr>
<td>V</td>
<td>Cow effluent Energy crops</td>
</tr>
<tr>
<td>VI</td>
<td>Cow and poultry effluent Energy crops</td>
</tr>
</tbody>
</table>

According to the data of table 1 it turns out clear that livestock effluents were only a part of the feeding: a deeper analysis showed that they were minimal both in terms of flowrate and (most of all) organic loading. The pie chart in Figure 1 emphasizes this situation considering the average data of case studies 2 to 6. According to data shown in figure 1, livestock effluents account for 40% in terms of flowrate and 24% in terms of organic loading (as VS), while energy crops and agro-waste together represent 60% of the flowrate and 76% of the organic matter fed to the anaerobic digester thus determining the real biogas production.

Figure 1 – Influent flowrate and organic loading percentage for livestock effluents, energy crops and agro-waste
The typical operational conditions and biogas yields of the plants are shown in table 2. All these systems operate in mesophilic conditions and are typically loaded at 2 - 3 kgVS/m³d. The corresponding retention times are quite high (always greater than 42 days), while typical yields are some 0.5 - 0.6 m³/kgVS and 1.0 - 1.5 m³/m³ per day. The methane content is around 50%.

Table 2 – Operational conditions and yields of the six anaerobic digestion plants studied

<table>
<thead>
<tr>
<th>Plant</th>
<th>OLR kgVS/m³ day</th>
<th>HRT days</th>
<th>T °C</th>
<th>Yields, SGP m³/kgVS fed</th>
<th>Yields, GPR m³/m³ day</th>
<th>CH4 %</th>
<th>CHP kWee</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.5</td>
<td>175</td>
<td>32 - 33</td>
<td>0.28</td>
<td>0.5</td>
<td>50 - 60</td>
<td>80</td>
</tr>
<tr>
<td>II</td>
<td>3.0</td>
<td>45</td>
<td>38 - 40</td>
<td>0.44</td>
<td>1.33</td>
<td>59 - 61</td>
<td>1042</td>
</tr>
<tr>
<td>III</td>
<td>2.1</td>
<td>42</td>
<td>Na</td>
<td>0.57</td>
<td>2.7</td>
<td>Na</td>
<td>845</td>
</tr>
<tr>
<td>IV</td>
<td>1.1</td>
<td>140</td>
<td>38 - 40</td>
<td>0.55</td>
<td>1.0</td>
<td>50</td>
<td>1042</td>
</tr>
<tr>
<td>V</td>
<td>3.0</td>
<td>77</td>
<td>39 - 41</td>
<td>0.60</td>
<td>1.76</td>
<td>49 - 51</td>
<td>1064</td>
</tr>
<tr>
<td>VI</td>
<td>3.5</td>
<td>67</td>
<td>38 - 40</td>
<td>0.52</td>
<td>1.88</td>
<td>49 - 51</td>
<td>845</td>
</tr>
</tbody>
</table>

Possible improvements of the process are related to both the increase of the organic loading rate and temperature. Lindorfer et al (2007) demonstrated the possibility of doubling the OLR in these systems without any particular consequence on the process stability but increasing the biogas production. Moreover, also temperature could be increased: Cavinato et al. (2010) have recently demonstrated the possibility of improve the biogas production and process stability passing from the mesophilic (37°C) to the thermophilic (55°C) range of temperature.

A well known drawback of AD is “ammonification”, that is the release of ammonia in the liquid phase of the digestate deriving from the hydrolysis of proteins. This fact clearly contrast with the necessity to reduce nitrogen loads form livestock effluents to values of 170 kgN/ha per year in most of the Po valley. Mass balances carried out in case studies II to VI demonstrated that ammonia nitrogen passed from 10% or less of the total influent nitrogen to 50-70% in the effluent nitrogen. In case study I ammonia was 80% of the nitrogen already in the influent and then reached 95% in the effluent. As a consequence, ammonia levels in the liquid phase of the anaerobic digestate were generally high: typical values were in the range 2-3 gN/L but could be as high as 6 gN/L. Therefore, a further step for nitrogen removal/recovery is needed.

In this study, one of the most crucial digestate for biological nitrogen removal was selected on the basis of ammonia concentration and salinity (case I, piggery). The SBR was inoculated with activated sludge coming from a demonstration SBR operating in the Treviso wastewater treatment plant, which stably follows the nitrite route treating the anaerobic supernatant from the co-digestion of waste activated sludge and biowaste. Once fed with digestate from piggery effluent, the SBR removed the nitrogen via-nitrate and the real-time control points on ORP, pH and DO were clearly visible on the profiles (see Figure 2).

In addition, the conductivity showed to be a reliable parameter to control the ammonia bio-oxidation (Figure 3) in spite of the high influent values. Thus, the feasibility of an automatic control based on the monitoring of indirect parameters was demonstrated.
For the industrial feasibility of control automation based on direct or indirect real-time parameters, we took also into account that the investment costs for the probes of direct measures (N-NH₄ and N-NO₃) amount to €8,000-12,000 euro, while €1,000-3,000 are required for indirect parameters (DO, pH, ORP, conductivity). In addition, indirect probes are currently more consolidated and their maintenance of indirect probes is cheaper and easy, even for inexpert plant operators.

Figure 3 – Profiles of conductivity and nitrogen species in a work-cycle

Conclusion

According to the study carried out, the following conclusions can be drawn:
the anaerobic co-digestion of livestock effluents and other high-energy-content biowaste, together with an increase of the organic loading rate and reactor temperature can further increase the economic incomes and the possibility to apply several techniques for the removal and/or recovery of nitrogen from the liquid phase of the anaerobic supernatant
the removal of nitrogen through biological processes like the SBR system can be a cheap and reliable technology to solve the problem of nitrogen management at present. In this study, the possibility of automatically control the bio-process by monitoring indirect parameters was demonstrated.

Literature cited


Reduction of nitrate leaching: economic feasibility of existing technologies, administrative procedures and financial instruments

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² Istituto Nazionale di Economia Agraria, Legnaro (PD)
³ Consultant

Abstract

This paper presents an analysis of the economic impact of Directive 91/676/EEC (‘Nitrate Directive’) on the agricultural activities in the lands that drain in the Venice lagoon (Veneto region). This is a strategic issue for the future development of the region’s agricultural sector, an issue strictly interrelated with not only rural development policies, but with renewable energy and water quality control policies as well. On the one hand, for the lagoon ecosystem to be preserved, it is important to limit nutrient pollution from those lands, which were indeed subjected to stricter restrictions on the spread of manure. On the other, an economically sizable livestock sector operates in the area.

Our study is organized in two parts. In the first one, we carry out an economic evaluation of several technological solutions and organizational arrangements that can potentially contribute to easing the trade-off between environmental quality and livestock activities. As a first step, we use a simple economic model inspired to Schnitkey and Miranda (1993) and Innes (2000) as a conceptual framework to examine the effects of improvements in logistics, incentives to anaerobic digestion and other policies on the spatial distribution of manure use, farm activity levels and profitability, environmental quality, and ultimately social welfare. In the second part, after presenting the general regulative framework related to Nitrate leaching, we look at the policy tools and the procedural aspects connected to the process of monitoring nitrogen emissions, effluent transport and processing by bioenergy plants. Some recommendations, based both on field observations and on the review of best practices in other European Union countries, are presented in the concluding remarks.

Keywords

Nitrate Leaching, economic feasibility, administrative procedures, Veneto Region

Introduction

The implementation of Nitrate Directive implies that livestock activities throughout Italy will have to reconsider the way they handle their effluents, since stricter constraints on agronomic utilization will become binding. The economic impact of the new regulation is expected to be particularly severe in the agricultural lands that drain in the Venice lagoon (Bacino scolante). On the one hand, for the lagoon ecosystem to be preserved, it is important to limit nutrient pollution from those lands, which were indeed subjected to stricter restrictions on the spread of manure. On the other, an economically sizable livestock sector operates in the area.

Our study is concerned firstly with the economic evaluation of several technological solutions and organizational arrangements that can potentially contribute to easing the trade-off between environmental quality and livestock activities in the Bacino Scolante. Secondly, after presenting the general regulative framework related to Nitrate leaching, we look at the policy tools and the procedural aspects connected to the process of monitoring Nitrate emission, effluents transport and processing by bioenergy plants.

Economic evaluation of several technological solutions and organizational arrangements

As a first step, we use a simple economic model inspired to Schnitkey and Miranda (1993) and Innes (2000) as a conceptual framework to examine the effects of improvements in logistics, incentives to anaerobic digestion and other policies on the spatial distribution of manure use, farm activity levels and profitability, environmental quality, and ultimately social welfare. Following Schnitkey and Miranda, we consider a profit maximizing farmer that raises livestock in a single facility and grows a crop on some given extent of land. To fertilize the crop, both commercial inputs and manure from the livestock operations are used. In the absence of any external constraints on manure spreading, the farmer finds it optimal to use manure only on the lands within some critical radius of the livestock facility, and commercial fertilizer only outside of that radius. Within
the critical radius, indeed, the rate of nitrogen application chosen by the mixed farm is higher than the rate that a crop farm would find optimal. The model enables us to compute the maximum amount of money the farmer can afford to pay for technologies and solutions that allow him to dispose of the manure at the point of origin.

When a limit on the amount of manure from nitrogen (e.g. Nitrate Directive) is enforced, the farmer reduces its manure application in the lands around the livestock facility, which causes both animal stocks (this has implications for planning solutions) and farm profits to decline. Notably, the radius within which manure can be viably used as a fertilizer remains unchanged. Once a constraint on manure application is in place, a decrease in the cost of spreading (e.g. because of a reduction in transportation costs resulting from the adoption of some technology) expands the area where manure can be economically used to fertilize the crop. Thus, technological solutions that result in smaller application costs for manure (e.g. improved logistics), in addition to partially offsetting the decline in livestock levels and farm profits induced by Nitrate Directive, have the potential to result in a more diffuse use of manure (at the low rates imposed by regulation). Changes in livestock diets and housing conditions, to the extent that they reduce nitrogen emissions from livestock, would have similar effects. In addition, such changes would improve farmers’ ability to pay for technological solutions.

While in the model there is in general a trade-off between profits from livestock and environmental quality, the spatial distribution of manure application is not irrelevant. For a given total amount of nitrogen application from livestock, manure could either be used at high rates in a relatively small area, or at low rates in a broader region. To a large extent, whether concentration or dispersion is more economically efficient for society depends on the shape of the damage function. If environmental degradation increases at increasing (decreasing) rates with nitrogen pollution, then more dispersed (concentrated) use of manure will be more desirable. As shown in the regional analysis by Innes (2000), many of the results above still hold when one consider a regional livestock sector rather than a single farm.

In the subsequent stages of the study, the model will be used as the building block for the economic evaluations of alternative solutions for handling livestock manure.

Regulative framework, policy tools and procedural aspects in Nitrate cycle governance process

A proper mix of policy tools and the definition of clear and transparent procedures for all aspects connected to the process of monitoring Nitrate emission, effluents transport and processing by bioenergy plants is an essential component of a nitrate leaching regional programme (EC, 2010; Oenema, 2004).

The most promising policy tools to be considered in implementing a regional plan for nitrate leaching reduction are the following one:

- “Nutrient emission rights” (NER) systems: a cap and trade scheme where every farm has a certain amount of emission rights allocated by the public regulatory body. NER can be trade among farmers; any transaction NER can be “taxed” with the reduction of NER value in order to reduce nitrate emissions. (see the example of the “manure rights” implemented in the Belgian Flandres - Anonymous (2006).

- “Manure bank”: a tools associated to the NER scheme, aimed at creating a transparent and easily accessible meeting point for the supply and demand of farmland to be used for manure spreading. The centralized exchange market can help to reduce transaction costs (contracts negotiation, price definition, etc.) and effluent transport costs. The manure bank costs can be covered by the users and by public subsidies.

- Management systems: standardized management systems, with supporting software, can be introduced in manure monitoring. A reference example is PLANET (acronimo di: Planning Land Applications of Nutrients for Efficiency and the Environment) a publicly available, open access software developed by the UK’s DEFRA (see www.planet4farmers.co.uk). A similar example is the software Sim-ba.N (Simplified Balance) developed by the CRPA in Italy www.crpa.it/nqcontent.cfm?a_id=4220) (Bortolazzo et al., 2009).

- Best Management Practices definition and use by farm extension services aimed at reducing nitrate output from different farm activities (OECD, 2005; Verspecht et al., 2009).

Conclusion

A last, more general point, is related to tariff differentiation: tariff actually granted to power producers based on renewable resources is not making any difference in relation to the raw material used; power deriving from biogas generated with specialized crops (i.e. corn in the Veneto Region) or by manure treatment is associated to different public externalities. State authorities should differentiate the premium prices granted to energy producers weighting the environmental and market impacts of different raw material use. With the same energy premium we run the risk of inducing an increased use of specialized crops as source of raw material for biogas generation, with negative impacts on the supply of feeding material to husbandry farms. This is a clear case of policy failure.
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Models of livestock waste management in Veneto and guidelines for the development of partnering management

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Abstract
This work identifies the organizational structure characteristic of current livestock waste management in Veneto and its bordering regions and, on the basis of these, proposes a few models using partnering management capable of paving the way for a cooperative development of livestock waste management at the district level.

Keywords
Livestock waste; organizational structure; models of partnering for livestock waste management.

Introduction
The objective of the section 7 of the Riducarefluoi is to identify cooperative district management models for livestock wastes flowing into the drainage basin of the Veneto lagoon. Every model of this type requires the elaboration of waste management protocols that take territorial and legal aspects into account while using an integrated chain within the sector. The context into which livestock waste management inserts itself includes not only constraints already established by standard community regulations for nitrate matter but also special opportunities rendered by the increase in value of biomass energy. These opportunities have become even greater in the past few years due to the governmental incentives which are given to companies producing energy from renewable resources, an incentive program undertaken by the European Union in response to international collaboration (the Kyoto Protocol).
The approach adopted in the current project was to analyze the current methods of livestock waste treatment in Veneto and to compare the various territorial approaches, for which the maturation of these methods is of significant interest.

Materials and methods
The applied methodology required the following phases:
- Analyses of current regulations related to and perform literature reviews of livestock wastes and the production of electric energy from renewable resources;
- Preparation of surveys for both key informants and livestock waste treatment firms;
- Interviews with key informants and experts on pertinent issues and/or working in relevant institutional areas;
- Census of the organizational structure of livestock waste treatment centers in Veneto and other regions of interest;
- Sampling and determination of cases to be further studied based on specific criteria: size, geographic location, corporation type, methods used for livestock waste treatment;
- Direct administration of questionnaires to the firms selected from among those sampled and determined to be of particular importance.
- Critical analysis of the study cases and grouping of the same by typology, which differs for the different organizational models;
- Prefiguration of the organizational structures best adapted to the objective of identifying models that can be replicated in or transferred to the current situation in Veneto.
- Analysis of the contractual, administrative and fiscal implications of the various partnering management models for the treatment of livestock wastes;
- Analysis of the social impacts due to the eventual development of livestock waste treatment plants managed cooperatively at the district level in the Veneto region;
- Elaboration of the guidelines for the development of the chosen models.

With respect to the phases outlined above, we have arrived to the point of prefiguring the organizational models that seem best adapted to the objectives of the project. Such progress is considered to be due to the directness of the survey studies
carried out in the region. The directness of the surveys has, in fact, allowed us to collect crucial information that otherwise may not have been obtained using other methodologies. We attribute this, in particular, to the existent organizational structure of the partnerships studied.

Results and discussion

The application of the methodology described above has allowed us to achieve the following results:

a) Census of the structures currently performing treatment of livestock wastes in the Veneto region, with particular reference to anaerobic digestion plants specializing in the production of electric energy from biogas;

b) Identification of the principal organizational typologies to which the various phases of waste management treatment may be assigned;

c) Prefiguration of the organizational models deemed most suitable for developing the initiative geared toward a partnering management style in the treatment of livestock wastes;

d) Identification in the economic, political and cultural arenas of the level of knowledge of the problems inherent to livestock waste management at the regional level and the identification of the level of interest in a diffusion of the livestock waste treatment structures into a partnering management style.

Giving more detail to the above points,

a) There are more than ninety firms specializing in the treatment livestock wastes using anaerobic digestion. There are more firms in the provinces of Verona, Padua, Venice and Rovigo, and more firms having an installed capacity superior to 950 kW.

As for the corporation designation, around 50% are managed as private companies, 43% as small private businesses, 6% as cooperatives, and 1% as consortia.

b) The organizational typologies delineated on the basis of the present research are outlined below:

1. Corporation structure with the character of a family business

   This is the most diffused corporate designation. In these companies the title ‘corporation’ is a practical formality and the company is managed for the most part as a small family business. This type of structure has arisen in order to diversify the sources of income of medium to large livestock farms. Such structures need enough agricultural land to permit both the production of animal feed and of the plant matter needed for the feeding of the digester. In this type of structure the destination of the digested material is almost always agricultural. In some cases the materials are used in innovative processes such as dehydration and phytodepuration.

2. Cooperative structure

   These structures are very important even though not well diffused; they are the fruit of long and complex relationships in which certain social groups consolidated in order to take advantage of timely market offers. Guided by people gifted in leadership, they are less dynamic than corporation structures, given the necessity of deciding together all strategic company decisions. But, on the other hand, they are generally endowed with larger agricultural areas and have facilitated access to credit.

3. Mixed public/private structure

   This type of structure was born with the aim of improving livestock waste management, and therefore these structures are often gifted in processes dealing with nitrate accumulation. In some cases, the creation of this type of company was initiated from the bottom by small breeder associations not ready or capable of managing a company of such complexity. In other cases it was initiated from the top (multi-utility), but the transformation of livestock waste was slowly stopped treating of waste water due to the low yield of biogas from this material and due to the difficulty on the part of the breeders to pay a fee for its holding. For the most part these companies treat materials coming from the food processing industry and from the urban sector (organic fractions of urban solid waste).

4. Industrial structure specializing in the transformation of livestock wastes into fertilizers

   This typology is made up of industrial plants which the treat fecal waste of poultry, horse and cattle. The wastes are transformed using compost and thermal/mechanical processes into commercial fertilizers and amendments.

   The distribution markets of such products are national and international, allowing the transfer livestock wastes to nitrate poor areas from areas with large concentrations of livestock.

5. Structures formed by technological offers

   This type of company is still not very common, but they appear to be in a phase of expansion. Here industries producing and distributing the equipment for livestock waste treatment directly support and manage the treatment plants, setting themselves up as an energetic entrepreneurs who support their local producers in order to increase profits coming from the marketing and production of the plant under their management.
c) Based on the structures found in the survey, the typologies deemed most suitable to the development of a partnership management style can be reduced to three models:
   1. The private corporation structure
   2. The cooperative structure
   3. Mixed public/private structure

These models, in our opinion, are capable of representing almost all of the current enterprise of this sector in the Veneto region, and therefore are also capable of increasing the development potential already inherent in the marketing and production fabric of this region.

d) Information revealed by key informants and experts revealed a strong consensus for the diffusion of partnering management for the treatment of livestock waste in the territory, however under binding circumstances of the socio-territorial, technical-managerial, and economic nature.

Conclusion

At the current state of progress, part 7 of the project Riducareflui has allowed for the identification of several partnering management models for the treatment of livestock wastes which, given their character, can be usefully inserted to the economic, territorial and social-cultural reality of the Veneto region. The next step along these lines would be to validate via a survey, the level of interest on the part of stakeholders in the sector. Furthermore, it will be necessary to plan guidelines that will facilitate the eventual promotion and diffusion of the validated models.

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Applied studies on phytodepuration by forested systems of digested slurry from biogas plants

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Abstract
Nitrate pollution is still a problem in some area of Europe and one of this is in Veneto Region, so a short-rotation forested systems and a productive woodland are tested as buffer areas.

Keywords
Nitrate leaching, digested slurry, infiltration forested systems, wooded buffer area, nitrogen emission

Introduction
The control of nitrate pollution can take place in two ways. Firstly, there is the direct control of input nitrate within the agricultural environment. The second way of action may be found in increasing the complexity of the landscape, not necessarily all over the catchment but in specific zones, especially within the river corridor, by implementing buffer zones. So within the “Reducareflui” project there are two sub-actions scheduled that focuses on phytodepuration, of digested slurry from biogas plants, by forested buffer systems.

Considering that water flow and nitrate leaching depend in part from natural precipitation and the amount, timing and species of nitrogen applied and on the other part on the soil characteristics two different experimental sites were set up: The Cerantola site (6.1) located in the upper part of the Veneto plain is characterized by permeable soil with the groundwater table at around 20 meters. In this site we are testing a short-rotation forested systems as a buffer zone.

The Diana site (6.2) located in the lower part of Veneto plain in a reclaimed area with impermeable clay soil and a groundwater table at around 1 meter. In this case the buffer zone is a monospecific (Platanus hibrida) productive woodland.

Moreover nitrogen emissions are investigated as the livestock manure is the most important source of atmospheric NH3 in Europe. Livestock slurries which have been digested anaerobically in biogas production plants could have higher NH3 volatilization potential than untreated slurries.

Material and methods
Description of the experimental sites
Cerantola site (6.1). It is located in quaternary aquifer made up of fluvial and alluvial deposit of the Brenta River, which form an unconfined aquifer of coarse sediments. In the upper 90 cm there is a soil characterized by a mixed of coarse and fine sediment with a presence of a tiny impermeable layer (15cm) with higher composition in clay and loam around 50-60 cm in depth. The climate is subcontinental with about 1000 mm rainfall per year.

This experimental site was set up with parallel ditches (1m depth) mainly to recharge the aquifer from diverted water of the closest stream (Brenta River) during high-water periods and out of irrigation season. As a second objective at the site, a short rotation coppice for wood biomass production has been planted between the ditches. On these two important objectives within this project, we are going to test one more challenging objective: the efficiency in nitrogen removal coming from anaerobically digested slurry produced in biogas plants and sprinkled between the tree rows.

The trees (Platanus hibrida) were planted in spring 2009 and considering that the first three years are part of the establishment phase and do not yield much dry matter, we are still in the maturation phase of this system.

Diana site (6.2) The experimental site is located within a forested buffer area of about 30 ha that was planted in 1999 in historically reclaimed land where the crop fields are lower than the River Zero. It is irrigated with freshwater from the river, so that the wet woodland can operate similarly to a natural riparian woodlands (see Boz and Gumiero, 2009; Gumiero et al, 2008).

The wooded wetland is located 15 km from Venice and the climate is subcontinental with about 800 mm rainfall per year.
The soil texture is extremely homogeneous, categorized as “silty clay loam” category (USDA-SCS).

The buffer system is divided into plots of the same size (0.35 ha each) and each plot is watered through a ditch system carrying water (through a lifting system) from Zero River. Its structure is characterized by ridges and furrows facilitating hypodermic water flow throughout the plot.

The experimental site covers a total area of two plots where trees were partially cleared to allow the slurry distribution and the remaining trees act as a buffer strip. One plot is irrigated as all riparian woodland while in the second one, there is no irrigation. In the first plot as a consequence of the irrigation (about 17,500 m³ year⁻¹), a perched aquifer is created with the water level always between 25 to 60 cm below the soil surface. The upper 15 cm soil layer (S) is subjected to the normal seasonal cycle. The second plot is characterized by the natural fluctuation of the water table.

Experimental design

Soil solutions from the unsaturated zone are sampled using suction lysimeters of 60 mm diameter - with a ceramic cup 70 mm in length – installed on each thesis at different depths. Sampling is carried out by applying a vacuum of 60 kPa to the suction lysimeter. Samples are taken every 3 weeks and more often during periods of intense rainfall.

Volumetric Sensors for Soil Moisture (Frequency Domain Reflectometry - FDR) to measure the water content in the soil are used. The concentration of Nitrogen species in the water and soil samples is analyzed using standard spetrophotometric methods. The mass of nitrate in the soil is calculated by multiplying the nitrate concentration at each sampling depth by the corresponding volumetric content of water measured by FDR.

The gas emission (NH₃ and N₂O) are estimated by the static camber method, ie measuring the rate of increase of ammonia concentration within enclosures put in the fertilized soil at different time.

Cerantola site (6.1). The experimental design provides a comparison between the short-rotation forestry area and meadows area whereby the areas will be divided into sub plots (3+3) which will be applied with varying quantities of slurry. In total there will be 6 sub plots, each sprinkled with 170 kg N/ha/y of digested slurry, 340 kg () and no slurry (control), respectively. Due to the high soil permeability it is mainly a vertical system, about 90 cm depth where hydrology and nitrogen concentration are monitored (Fig. 1).

Diana site (6.2). Besides the monitoring of unsaturated layer described above, to understand water movement between the saturated and unsaturated zones, the fluctuation of groundwater levels were monitored continuously by five wells located in both plots (Fig.1).

Samples of the groundwater were taken at the same time as the samples from suction lysimeter. The site has impermeable soil therefore the quantity and quality of runoff are also measured.

Figure 1 – Experimental design of the two sites.

Results and discussion

The first months of the project were used to understand the local hydrology and define the monitoring plan in both sites. Cerantola site (6.1.) Due to the consistent presence of cobble in the soil, one of the first difficulties met was to single out
suitable methods to apply the slurry on this permeable soil. So the two amounts (170 and 340 N kg/ha/y) of digested slurry have been spread in three parts with two of them having been already done (12/05 and 29/06). During the first application, and only in the wooded areas, the slurry was buried into the soil to avoid nitrogen emission. On the other hand this caused us to lose an important buffer layer of 15-20 cm so in the second application the digested slurry was sprinkled on the top soil of the wooded area as well as in the meadow. Ammonia emission after the second distribution was high for about three hours after the spreading and dropped almost completely within 48 hours. The further development of these preliminary data will estimate the global atmospheric loss of nitrogen, which in the second operation of spreading seemed to be less than 10% of the nitrogen released, with little differences between the two doses of distribution.

The continued measurement of water volume in the soil by FDR (Fig. 2) underlines how the layer at 60 cm is often more wet than the upper layer to show that the hydraulic conductivity is slowed down at this depth. This aspect could be a keypoint for the buffering capacity of the system. Moreover the high soil porosity allows a fast nitrification process and as a consequence the high ammonia concentration of the digested slurry disappears quickly. So far there are no significant differences between short rotation coppice and meadow treatments.

Global nitrogen balances can be carried out by estimating nitrogen emissions into the atmosphere.

Figure 2 – Volumetric water content of soil in the two treatments measured by FDR.

Diana site (6.2). The impermeable clay-soil makes the system very conservative and as a consequence the digested slurry was applied within parallel furrows 10-15 cm depth and sprinkled with the whole quantity (340 N kg) at the same time (14 of June). Nitrogen emissions were higher and longer than in the Cerantola site, depending on the highest distribution dose and the prolonged stagnation of digested slurry on the soil surface.

Soil analysis shows a quite slow nitrification process and as a matter of fact, a month after slurry distribution, in the same area, we recorded high value of nitrogen (around 300 mg/L) mainly as ammonium and nitrite in the upper soil layer. Then, after 20 days about 50% of the ammonium was oxidized in nitrate.

From the first results of water collected within the lysimeter (Fig. 3) it was possible to see how the two treatments (irrigated and no irrigation) act differently. The irrigation water seems to actively wash the nitrate produced by the digested slurry toward the lower layers at 30 and 50 cm depth. As a result the nitrate concentration increased (up to 86 mg/L) also in the artificial aquifer sample in the well located on the edge between the distribution zone and the wooded buffer zone. In the area without irrigation all nitrogen has remained in the same place where ammonium is slowly converting into nitrate.
Figure 3 – Nitrate concentrations of water at different depths in the two treatments (FA=irrigated; FN=non irrigated), a=in the sprinkled zones, b=in the edge between sprinkled zone and buffer wooded strip.

Conclusion
The two sites should not follow the same strategy and policy in digested slurry distribution but need specific method and machinery that must be better tested.

Cerantola site (6.1) In this system it is perhaps not possible to avoid nitrogen atmospheric emissions without compromising the buffering capacity of the system. There is a trade-off between the aerial emissions caused by superficial application of the slurry and the nitrate leaching into the groundwater resulting from burying (to 15cm) the slurry within the 80-90cm soil layer. It is not possible to claim whether the short rotation system is more or less efficient in the meadow area in respect to the buffeting of nitrogen as we are still during within the maturation stage.

Diana site (6.2). From the first results it seems that, in terms of buffering capacity, the non irrigated zone is better than the irrigated one. Without irrigation the digested slurry is stored in the upper soil until heavy rain moves it very slowly toward the ground water. Thanks to this conservative situation the nitrogen amount could be used more efficiently by the vegetation (uptake) or converted into gaseous molecules throughout the denitrification process. At this stage is not possible to quantifying the buffer efficiency of the two plots.

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Treatment of animal manure through constructed wetlands wastewater treatment for reducing nitrogen load: system description and first results

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Abstract
This paper presents the preliminary results of a full-scale hybrid constructed wetland for tertiary treatment of piggery manure. The system comprises one vertical flow constructed wetland composed by three units of 5m2 and one horizontal flow constructed wetland of 106 m2. The comparison of median inlet and outlet concentrations of wastewater sampled from March to August 2010 showed that the constructed wetland system reduced abated COD by 66.7%, NO3-N by 54.1%, NH4-N by 51.9% and TN by 58%.

Keywords
Hybrid constructed wetland system; Swine wastewater; Nitrogen forms; COD.

Introduction
The environmental impact of the livestock sector in North-East Italy directly affects water (nitrates accumulation and eutrophication). Disposal of animal wastewater is a common problem among local farmers, land spreading is the usual disposal method but requires sufficient land area in close proximity to the farm. In addition, the EU Nitrates Directive (S.I. 378, 2006) has imposed restrictions on land spreading. Problems associated with animal wastewater treatment and land application has prompted an urgency to find alternative treatment systems that are technically feasible and economically viable for the European and Italian farms. Integrated constructed wetlands (ICW) are therefore being considered as an alternative method for livestock wastewater disposal which could reduce the amount of land necessary for terminal land application (Knight et al., 2000). Constructed wetland systems provide a low-maintenance, cost-effective option for further treating pretreated waste streams. These man-made wetlands replicate the same general components of natural wetlands (soil, microbial activity, vegetation, etc.) and can reduce nutrient, BOD, and suspended solid loads. These contaminants are transformed or inactivated by a combination of physical, chemical, and biological processes inherent to wetland systems. In Italy the majority of wetland plants are operating on civil wastewater, some treat agricultural runoff and vinery wastewater. The application in livestock growing sector is almost unknown, but the performance of the vegetated systems is promising (Salvato and Borin, 2010). This paper presents the first results obtained monitoring a full-scale hybrid wetland system operating on a swine farm.

Material and methods
The study is in progress on constructed wetland at a swine farm in Carmignano di Brenta, Padova -Italy. The farm grows 1000 pigs with an average weight of 80 kg. Waste generated in the swine facility is flushed to pre-treatment that consists of an initial physical separation into liquid and solid fraction, N reduction in the liquid fraction takes place in an activated sludge reactor by a nitrification and denitrification process. The effluent from the activated sludge reactor is collected in an interred tank that feeds the hybrid wetland system twice per day. The full-scale hybrid system was designed to treat 5 m3/day of wastewater and is composed of three subsurface flow vertical systems (VF), (10 x 0.70 x 0.70 m) operating in parallel followed by one horizontal cell (HF) (26.5 x 4 x 0.70 m) (Fig. 1).
The first VF (VF1) is filled with gravel (ø 10-20 mm) and planted with Canna indica L. (Fig. 2), the second (VF2) is filled with gravel (ø 10-20 mm) and planted with Phragmites australis, and the third (VF3) is filled with gravel (ø 10-20 mm) to a depth of 0.10m followed by coarse sand (ø 3-5 mm) and zeolite stones and is planted with Phragmites australis. The horizontal sub-surface flow system (HF) receives the partially treated waste from the outflow of the vertical systems via a pump, it is filled with gravel (ø 10-20 mm) and planted with Phragmites australis (Fig. 2) and some Iris pseudacorus, Carex pseudocyperus and Juncus effusus.

Waste water effluent discharged from the horizontal flow is collected in an interred tank and recycled for cleaning the swine facility. Samples have been collected twelve times from March to August 2010. The performance of each element of the hybrid system is being assessed by measuring the concentration of: COD, nitric nitrogen, ammoniac nitrogen, total nitrogen and dissolved oxygen. Sampling points are in the inflow water (IN), at the outlet of each VF, at the inflow of the HF (IN-HF) and at the HF outlet (OUT-HF).
Results and discussion

During the monitoring, COD concentration was slightly abated by the three VF cells and the HF gave the higher contribution to the removal. Similar trends were observed also for total and ammoniac nitrogen (Fig. 3). The vertical cells eliminated ammoniac nitrogen without generating the nitric form. As expected, nitric nitrogen concentration in the inflow wastewater was quite low and was slightly abated by the vertical cells. The HF system gave a further contribution to the elimination of NO3-N. Considering the median values, VF1, planted with C. indica seemed to have better performance than the two cells planted with Ph. australis. The same consideration is not confirmed taking into account the concentration corresponding to the third quartile.

Figure 3 – COD, total nitrogen, ammonium nitrogen and nitric nitrogen concentration from different outflow sample points

Table 1 compares the removal efficiency (R.E.) for the parameters monitored in full-scale constructed wetland. It was calculated as: R.E. = [(CIN - COUT-HF/CIN)×100, where CIN and COUT-HF are the concentrations at the inlet of the system and at the outlet of the HF. The median COD was removed with of 66.7%, (inlet 300 mg/L; outlet 99 mg/L), and with maximum values from inlet of 1183 mg/L and outlet of 305 mg/L; total nitrogen removal efficiency was 58% for median value, with highest performance measured in third quartile (91.6%); ammonium nitrogen abatement was around 52% and 2% for median and third quartile respectively (inlet 182 mg/L and outlet 179 mg/L); finally, nitric nitrogen was removed with median value of 54% and 50% in third quartile.

Table 1 – Removal efficiency of the hybrid system for COD, total nitrogen, ammonium nitrogen and nitric nitrogen

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Inflow (mg/L)</th>
<th>Outflow (mg/L)</th>
<th>R.E. (%)</th>
<th>Inflow (mg/L)</th>
<th>Outflow (mg/L)</th>
<th>R.E. (%)</th>
<th>Inflow (mg/L)</th>
<th>Outflow (mg/L)</th>
<th>R.E. (%)</th>
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<td>COD</td>
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<td>210.7</td>
<td>59.7</td>
<td>1183</td>
<td>305.5</td>
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</tr>
<tr>
<td>tot N</td>
<td>175.6</td>
<td>73.7</td>
<td>58.0</td>
<td>202.5</td>
<td>105.6</td>
<td>91.6</td>
<td>346</td>
<td>183</td>
<td>47</td>
</tr>
<tr>
<td>NH4-N</td>
<td>138</td>
<td>66.3</td>
<td>51.9</td>
<td>164.6</td>
<td>105.9</td>
<td>35.6</td>
<td>182.1</td>
<td>179</td>
<td>2</td>
</tr>
<tr>
<td>NO3-N</td>
<td>3.58</td>
<td>1.64</td>
<td>54.1</td>
<td>3.87</td>
<td>1.93</td>
<td>50.0</td>
<td>4.23</td>
<td>3.13</td>
<td>26</td>
</tr>
</tbody>
</table>

In table 2 the R.E. only of the horizontal sub-surface flow system (HF) is considered. R.E. for COD was the same (66.8%) as for the entire system taking into account the median value, while it was slightly lower for the higher concentrations (maximum values from inlet of 665 mg/L and outlet of 305 mg/L). R.E. was 45% on median value for total nitrogen, 37% for ammonium nitrogen and 24.4% for nitric. For all the forms of N the removal efficiencies decreased increasing the values at the inlet (3rd quartile and maximum).
Table 2 – Removal efficiency of the HF system for COD, total nitrogen, ammonium nitrogen and nitric nitrogen

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median In-HF (mg/L)</th>
<th>Median Outflow (mg/L)</th>
<th>Median R.E (%)</th>
<th>Third quartile (Q3) In-HF (mg/L)</th>
<th>Third quartile (Q3) Outflow (mg/L)</th>
<th>Third quartile (Q3) R.E (%)</th>
<th>Maximum values In-HF (mg/L)</th>
<th>Maximum values Outflow (mg/L)</th>
<th>Maximum values R.E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>301</td>
<td>99,9</td>
<td>66,8</td>
<td>409,5</td>
<td>210,7</td>
<td>48,5</td>
<td>655</td>
<td>305,5</td>
<td>58,8</td>
</tr>
<tr>
<td>tot N</td>
<td>134,2</td>
<td>73,7</td>
<td>45</td>
<td>157,4</td>
<td>105,6</td>
<td>32,8</td>
<td>300</td>
<td>183</td>
<td>39</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>108,1</td>
<td>66,3</td>
<td>38,6</td>
<td>144,3</td>
<td>105,9</td>
<td>26,6</td>
<td>184</td>
<td>179</td>
<td>3</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>2,17</td>
<td>1,64</td>
<td>24,4</td>
<td>2,48</td>
<td>1,93</td>
<td>21,9</td>
<td>3,46</td>
<td>3,13</td>
<td>9,53</td>
</tr>
</tbody>
</table>

Conclusion

Preliminary results show that application of a full-scale constructed wetland for tertiary treatment could be a very effective approach to swine wastewater management. The constructed hybrid wetland in our experiment demonstrated an efficient removal of total N and ammonium nitrogen from the pre-treated manure, without generating NO₃-N. On the basis of these results an improvement to the system has been designed and will be implemented during 2010, consisting of set the loading system to operate at programmed times to facilitate the oxygenation of each vertical unit and a final basin with a floating system to increase treatment efficiency. Monitoring will continue in order to validate the improved system.

Acknowledgements

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Literature cited


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from livestock effluents
in the Veneto lagoon drainage basin

October the 4\textsuperscript{th}, 2010