Nutrients Pollution Control Associated with the Production of Biogas from Manure and Agricultural Waste

Mihaela FRINCU, Naiana MILEA, Paul POPA, Stefan NICOLAU
Ministry of Environment and Climate Change, Romania, Project Management Unit
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Abstract

The anaerobic digestion of manure and agricultural waste has related benefits for agriculture, energy generation and environmental protection. In the locality of Seini, manure and slurry from animal farming are causing the pollution of surface- and groundwater (nutrients discharge) and air (smell, release of greenhouse gases).

This paper reviews the environmental improvements obtained through the implementation of biogas plants in other European countries and infers the opportunities for nutrients pollution control that could be achieved by operating a biogas plant in Seini, Romania.

Keywords: biogas, manure, slurry, agriculture, waste, nutrients pollution control, greenhouse gas emissions reduction, climate change mitigation.

Introduction

In the absence of adequate waste management systems, animal farming can pose severe environmental problems, such as loss of nutrients to water bodies and release of powerful greenhouse gases like methane and nitrous oxide.

The anaerobic digestion decreases the solids content of manure and slurry, thus making it easier to incorporate in the soil and increases the share of ammonium compounds which are more available to the plants. When the digestate is stored and applied correctly to agricultural land, greenhouse gas emissions can also be reduced, thus achieving the integrated pollution control of soil, water and air.

The biogas resulting from anaerobic digestion can be used for cogeneration of electricity and heat, contributing to the achievement of the renewable energy targets and to the reduction of CO_2 emissions from fossil fuels, having a positive contribution to climate change mitigation.

1. Literature review

There are several papers regarding research and experience with biogas from different feedstocks in Europe, including sludge from wastewater treatment plants, by-products from biofuels production or from the food industry, along with different kinds of domestic, industrial and agricultural waste.

This review mainly focuses on nutrients management in raw manure and slurry and digestate, on the impact on surface and water quality and on the implications for reducing greenhouse gas emissions and for climate change mitigation.

1.1 Increased nutrients availability

In order to obtain high yields and good quality crops it is essential to supply the plants with nutrients in the right amount and at the right time. Manure and slurry have the advantage that, apart from nitrogen (N), they contain also all the other macro- and micronutrients that the plants need. These elements are also important for the anaerobic digestion of manure and slurry, as the methanogenic bacteria also need a complex substrate to feed on.

Several studies have highlighted that the anaerobic digestion increases the ammonium content of the substrate and decreases the nitrates content. A very thorough review of research results is presented in the report by Smith et al. 2007. According to their review, with the exception of dairy cattle in Kent, all the other experiments show increases of the percentage of ammonium in the total N content of the digestate ranging between 11.3-52.0% (Smith et al. 2007). However, nutrients uptake by plants depends on many other factors, like soil type, time and method of application, crop needs.

1.2 Reduced nitrogen leaching

The main characteristic that reduces N leaching is that ammonium is less mobile in the soil than nitrate so, if the anaerobic digestion increases the ammonium content, N will be both less mobile and more available to the plants. Knudsen and Lemming refer to some studies that have been done in Denmark for pig slurry and the model has shown that if some of the nitrogen fertilisers are replaced with slurry, in the case of digested slurry N leaching could be reduced by 3 kg N/ha/year. Bondgaard estimates for his study case in Bornholm that the reduction of N leaching achieved by applying digested slurry instead of untreated slurry could be in the range 1.5-3 kg N/ha/year (Bondgaard 2012).

However, slurry has a much higher water content than manure, so producing biogas from slurry would involve the transport and storage of large amounts of water to the plant and from the plant to the fields. It is generally recommended to apply the slurry directly on the cultivated fields or to separate the organic fraction before digestion.

1.3 Reduced odour and contaminants content

The unpleasant smell of manure and slurry is given by the volatile organic compounds, like short-chain fatty acids, which are broken down during the anaerobic digestion process into CO_2 and water which are odourless, thus resulting in reduced air pollution. Depending on the temperature inside the digester, a lot of the germs and weed seeds in the manure and slurry are also destroyed, thus contributing to better yields and healthier crops. The higher the temperature in the digester, the more germs and weed seeds are destroyed (Birkmose and Pedersen, 2008).

1.4 Reduced greenhouse gas emissions

Greenhouse gases have different global warming potentials and periods of persistence in the atmosphere. Methane and nitrous oxide are greenhouse gases that originate mainly from agriculture and landfills and have a high global warming potential (Table 1).

The anaerobic digestion of manure and agricultural waste reduces the methane emissions to the atmosphere by controlling the process of organic matter decomposition and capturing the resulting biogas, which is further used for energetic purposes.

Table 1. Global Warming Potentials of CO_2, CH_4 and N_2O

Source: Climate Change 1995, The Science of Climate Change: Summary for Policymakers and Technical Summary of the Working Group I Report, page 22.

Species	**Chemical formula**	**Lifetime (years)**	**Global Warming Potential (Time Horizon)**		
			20 years	**100 years**	**500 years**
CO_2	CO_2	variable	1	1	1
Methane	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170

2. Environmental challenges in Seini

Intensive animal farming and the lack of adequate wastewater treatment and manure storage facilities have led to the pollution of surface and groundwater, as well as to serious air pollution (smell) as presented briefly below.

2.1 Presentation of Seini

Seini is a town with about 10,000 inhabitants located in the northwest part of Romania. It has an administrative area of 5,891 ha out of which 3,965 ha agricultural land. The main activities are agriculture and animal farming, with orchards and vineyards in the eastern part of the town.

2.2 Manure and agricultural waste

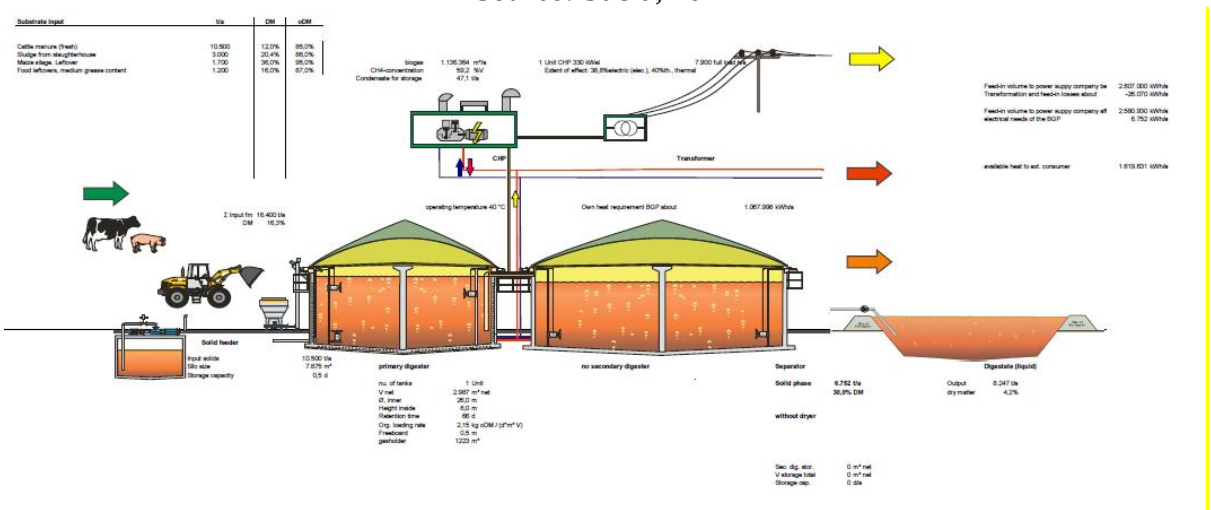
There are several animal farms with a total livestock of 811 cattle, over 1.6 million laying hens and about 30,000 pigs. The total amount of animal manure is over 115,600 tons/year. In addition to this, there are also significant amounts of biomass and organic waste resulting from other farming activities, such as degraded maize silage.

2.3 Environmental issues

Untreated wastewater from animal farms is discharged directly into the Zugau and Seinel rivers, that flow into the Somes river. Both groundwater and surface water are polluted, and the surface water also has an extremely unpleasant smell that disturbs the inhabitants of Seini, as some of the wastewater passes through the center of the town. The main reason for water pollution is the absence of sewerage and wastewater treatment systems and also a lack of waste management systems for the animal farms. The town of Seini has a sewerage system for domestic wastewater that serves only 9% of the population and no wastewater treatment plant.

Seini is located in an area that is vulnerable to nitrates pollution and thus certain water protection measures have to be taken, such as limiting the amount of manure that can be applied on the agricultural land as fertilizer and restricting the period of application to the crops growing season.

Fig. 1: Schematic representation of the proposed biogas plant
Source: Suciu, 2012



3. Proposed solution for Seini

The solution recommended for Seini is a biogas plant with a capacity of 370 kW using as substrate for anaerobic digestion:

- 5,000 t/year waste from pig farms
- 12,000 t/year waste from cattle farms

- 4,000 t/year waste from poultry farms
- 2,000 t/year degraded maize silage.

3.1 Technical solution

The biogas plant will have appropriate storage facilities, two circular digesters (a primary and a secondary digester with a diameter of 26 m and wall height of 6 m) operated in mesophilic temperature range (38-40ºC). The digesters will be covered with a double membrane for biogas collection and the produced gas will be used in a combined heat and power (CHP) unit. The electricity will be supplied to the public grid, some of the heat will be used to maintain the temperature in the digesters and the excess will be used for other industrial processes (Suciu, 2012).

3.2 Expected environmental benefits

The most important expected environmental benefits are the reduction of nutrients loss to the water bodies and the reduction of smell from the farms and the rivers passing through the town. In addition to this, through improved nutrients management an increase of crop quality and yield, as well as a reduction of artificial fertilizers input can be expected, leading to economic benefits.

3.3 Precautions

Digested manure and slurry have a higher ammonium content than the raw matter, which increases the risk of ammonia loss to the atmosphere. Precautions must be taken for proper storage of the raw matter and digestate to avoid nutrients leaching and greenhouse gas emissions. The application of the digestate on agricultural land must be done with special equipment (injection) and only during the periods when the crops have a high demand of nutrients to optimize uptake.

4. Conclusions

The anaerobic digestion of manure and biomass can have multiple environmental benefits such as improved fertilizer quality, reduced nutrients leaching, reduced odour and greenhouse gas emissions. In order for the biogas production to be feasible also from the economical point of view it is important to chose the location of the plant in an area where the feedstock is available in large enough quantities with minimum transport distances, and also that enough agricultural land is available where the digestate can be applied as a fertilizer, also with minimum transport costs. Adequate storage facilities are essential to prevent the pollution of soil, water and air, and special equipment is needed to apply the residue on land with minimum nutrients loss.

The biogas plant that is planned for Seini could contribute to significant environmental improvements, by providing facilities for manure and agriculture waste management and also by producing electricity and heat from biogas.

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