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Iranian Journal of Energy & Environment

Journal Homepage: www.ijee.net

IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Modern Technologies of Natural Manure Treatment in Livestock Production

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P A P E R I N F O

Paper history:
Received 21 January 2019
Accepted in revised form 10 March 2019

Keywords:
Ammonia
Greenhouse gas emissions
Natural manure
Slurry management
Slurry separation
Slurry cooling
Anaerobic digestion

A B S T R A C T

About methods of reduction of ammonia emissions and greenhouse gas (GHG) from livestock production were investigated. Many techniques required high investments costs by low reducing level of emissions. Among all known methods, the most effective method is slurry cooling and decreasing slurry pH to obtain high ammonia emission reductions. When we talk about GHG, anaerobic digestion and slurry separation are desired solutions. Regarding sustainable development in agriculture production, not only environmental effects, but also economy is important.

***doi**: 10.5829/ijee.2019.10.01.07*

INTRODUCTION

Production of livestock animals is a main source of harmful gas like ammonia, and GHG like methane [1, 2]. Reducing of NH_3 emissions has two aspects: environment, as it is one of the main source of nitrogen losses to the atmosphere and agro-technical; because of decreasing the fertilization value of natural manure, especially in slurry form. N_2O is mainly emitted from soils, but ammonia through transformations is produced from this process is important.

Literature review has demonstrated many techniques in mitigating of ammonia and GHG emissions on the whole production chain. Recent research studies in Europe in countries around Baltic Sea, involved in an INTERREG project about slurry acidification and countries around Mediterranean Sea involved in other EU project showed that among all techniques of reducing ammonia emissions one of the most effective is slurry acidification. Only dual approach is worth to perform: environmental and agro-economical. All ammonia emission mitigation measures have both advantages (decrease in harmful gas and odour emissions) and disadvantages (high investment costs). Therefore, many researchers concentrate not only on environmental problem but also on economic aspects of implementation [3-5]. Because some of tests conducted in Italy [6], results showed that the odour and ammonia emissions from digestion processes are higher than from urea, then some techniques may have potential to reduce ammonia emission from digestion would be worth to consider. Summary of livestock species to global GHG emissions is shown in Table 1. Also, Figure 1 illustrates GHG emissions from livestock wastes.

REGULATIONS FOR AMMONIA AND GHG EMISSION REDUCTION

Regarding livestock animal conditions in livestock buildings there are law regulations, both on European and on country levels. According to Polish Ministry of Agriculture and Rural Development from 28 of June 2010 in matter of minimal conditions of livestock animal housing, the protection norms were established. The microclimate factors (ventilation rates, dust, air temperature and humidity and harmful gases concentration) in livestock rooms should be maintained on no-harmful levels [7].

These regulations are the consequences of implementation in Poland such EU directives:

- Directive of Council 91/629/EEC from 19 November 1991 about minimal standards of calves protection,
- Directive of Council 97/182/EC from 24 February 1997 about minimal conditions of calves protection,

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TABLE 1. Contribution of livestock species to global greenhouse gases (GHG) emissions [1]

	GHG emissions (mln ton- eq. CO_2· year^{-1})			
	CO_2	CH_4	N_2O	Total Emission
Cattle	1166.2 (61%)	2072.8 (81%)	661.6 (60%)	3900.6 (70%)
Small ruminants	69.9 (4%)	244.5 (10%)	202.6 (18%)	517.0 (9%)
Pigs	338.9 (18%)	237.3 (9%)	131.1 (12%)	707.3 (13%)
Poultry	332.2 (17%)	-	107.3 (10%)	439.5 (8%)
Total	1907.2 100%)	2554.5 (100 %)	1102.6 (100%)	5564.3 (100 %)

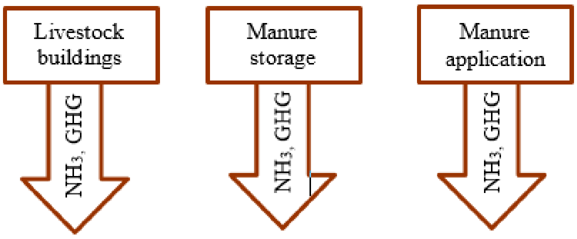

Figure 1. Gaseous emissions on manure management stages

- Directive of Council 97/2/EC from 20 January 1997 for minimal standards in calves protection.

According to Law Regulation about Animal Protection, everybody who is keeping livestock animals, should ensure them proper housing conditions [8].

The highest reduction rates have techniques approved as best available techniques (BAT) by European Union, actualized and mentioned in the Decision of Council [9]. BAT were defined for the first time in article 2, point 11 of IPPC Directive [10]. According to the polish law system they were introduced in year 2001 forvEnvironment Protection. "The best" mean that techniques are most effective and at most modern level of activity development and methods of their introduction in order to have possibility in practice prevention and reduction of emissions.

REDUCING OF EMISSIONS

Among BATs, there are following techniques for ammonia reduction: slurry acidification, bio filters, slurry cooling, manure storage covers, anaerobic digestion. Slurry acidification resulted in significant reduction effect on all manure management stages: in livestock buildings, from manure storage and in the course of application on field. Literature overview of reducing methods of ammonia emissions was completed by Monteny and Conference [11] which is shown in Table 2.

Slurry acidification

Slurry is usually a mix of manure and urine from livestock, bedding material with small structure like sawdust or chopped straw, washing water, water spill, etc and originating from stables with whole or partly slotted floors. Normally, slurry has a dry matter content of 2-10% when brought to the fields for fertilizing. Typically about 70% of the dry matter is organic matter.

Slurry acidification is a good chance for ammonia reduction through implementation of project within Interreg, Baltic Sea Region under title" Reducing of nitrogen loss by promotion of slurry acidification technologies in Baltic Sea Region". There are three different SAT techniques: in-house, in-storage and in-field. In-house Slurry acidification enables to reduce ammonia emissions at the early stage of natural manure management, and further also during storage and application. In Denmark, using slurry acidification has approved effect of NH_3 emission reducing like injection. Now in this country 20% of all slurry is acidified, and there are plans for year 2050 for all slurry to be acidified.

Lowering pH in slurry displaces the chemical balance between NH_3 (ammonia) and NH_4^+ (ammonium) towards $NH4^+$. The formation of NH_3 stops at a pH lower than 6. Less ammonia emissions, 50 % reduction from cow farms, 64 % reduction from pig farms; [19] as well as CH_4 production with lower emissions about 64-72% [20] were resulted. Figure 2 shows schematic diagram of in-house" installation for slurry acidification.

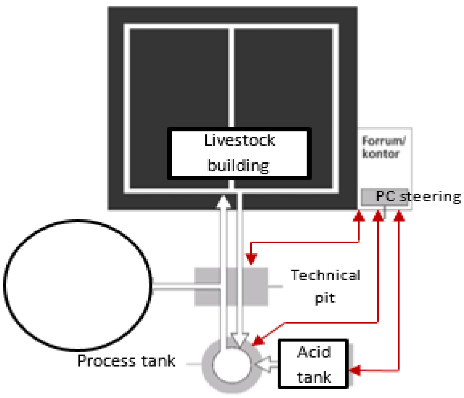

Figure 2. Schematic diagram of "in-house" slurry acidification technology [21]

TABLE 2. Methods of NH_3 reduction for dairy cattle in % compared to livestock buildings with slatted floors [11]

Measure	Process involved	Control factor	Maximal reduction	References
Feeding strategies	urine and manure production	urea concentration	39	[12]
Slurry handling *water flushing	enzymatic conversion	urea concentration	17	[13]
*formaldehyde flushing	enzymatic conversion	urease activity	50	[13]
*slurry acidification	dissociation	pH	37	[14]
+ additionally flushing slats with acidified slurry	dissociation	pH	60	[15]
Floor Systems	air exchange/volatilization	air velocity	52	[16]
*v-shaped floors + flushing with water	enzymatic conversion	urea concentration	65	[17]
+ formaldehyde flushing	enzymatic conversion	urease activity	80	[14]
Housing systems	volatilization	emitting area of floor/pit	10	[18]
* reduced slatted floor area * tied-up stalls	volatilization	emitting area of floor/pit	28	[18]

It is possible of automated pH control of slurry. Sulfuric acid is stored in special tank, which is located on a small concrete platform. The only additional cost, comparing to other two SAT techniques is costs for making a platform, where the sulphuric acid tank will stand, as well as a tank for mixing, which shall coming from the stables.

In an in-house acidification system for cattle, the system starts by filling all slurry channels with 80 cm of slurry. In a new house it is possible to add water as well. At start-ups acidifying is provided in steps of 0.05 pH down every day. Mixing the slurry starts, pH is measured and acid is dosed until the pH is lowered of 0.05 in all of the slurry. The process is done in about 30 minutes for example 300 m^3 of slurry. The startup process is repeated every day for a couple of weeks until the pH is reaching to a level of 5.5 in all of the slurry. The acidification is performed with animals inside the barn, but acid is dosed into the slurry in *a mixer room* connected to the channels. Tank for mixing of slurry should have a size that equals 5-7 days production of slurry [21].

The acidification process can reduce risk of gaseous emissions and odour problems. A Danish study has demonstrated that frequent adjustment of the pH of slurry in a livestock building for fattening pigs with 1/3 drained floor and 2/3 slats reduced ammonia volatilization by 70% [22].

Using acidified slurry in a biogas plant

Slurry fibres from the acidified slurry gives 50 % more gas than non-acidified fibres, and can be added at up to 30 % of the biomass.

Slurry cooling

Ammonia evaporation is negatively correlated with the temperature. Cooling the slurry in the slurry channels with an effect of 24 W/m^2, the slurry channel has been verified to give 31% reduced ammonia evaporation [23].

The effect on evaporation depends on the housing system and the cooling effect. Slurry cooling is established by embedment of plastic (PEL) tubing at the bottom of slurry or manure channels in the stables. The hoses are typically laid with a distance of 35-40 cm. In stables with slurry systems, the cooling hoses are alternatively laid directly on top of the channel bottom. The cooling tubes are connected to a heat pump. Liquid cooling is most relevant in pig herds in which the recovered heat can be used for heating purposes, which typically involves herds with sows and piglets. An additional effect is 60% reduced ammonia evaporation during field application, equal to an increase in the bio-availability of the nitrogen in the slurry of about 20% [23].

Floating elements of heat exchangers allow for slurry cooling. Results of work under exploitation of heat exchangers in production environment show 7-74% of decrease in ammonia emission [24].

The purpose of manure cooling is to reduce NH_3 emissions. NH_3 volatilization from manure is dependent on the temperature of the manure; accordingly, cooling of the manure reduces the ammonia evaporation. Manure cooling also reduces CH_4 and CO_2 emissions as cooling reduce the growth of methanogenic bacteria [25].

Manure cooling of pig manure can be installed either under the manure canals (in new buildings) or above the concrete via cooling pipes in the bottom of the canals. The cooling pipes are connected to a heat pump, and the recovered heat from this can be used for the heating purposes (for example in the housing units for weaning pigs or farrowing sows).

A typical installation cost in Denmark in the neighborhood is from 150,000 to 250,000 DKK depending on stall size; but, this investment is to be compared to how expensive it is to heat livestock buildings and farmhouse with oil. Compared with a large herd, which produce 16,000 piglets a year, and 1 200 sows, calculations show that farmers typically use about 45,000 litres of oil per year. It is a great expense that will be spared when you move to the slurry cooling, which in principle seems completely like geothermal. In Danish conditions, the payback time in slurry cooling facilities is just 2-5 years. The ammonia evaporates from the hot slurry. The slurry stays warm, because over time the bacteria will increase that develop methane. According to Bolt-Joergensen farmers can reduce the evaporation of ammonia with slurry cooling up to 31 percent over a full year. At the same time, CO_2 emissions from the cool slurry lowered since the bacteria developing methane does not have good growing conditions. When the ammonia evaporation is reduced, the slurry is containing a higher level of nitrogen, which increases the manures fertilizer value. The hot slurry is pure energy, with vagaries in the stables and for the farmers house [25].

Biofilters

Chemical air cleaning has been proven to remove 90% of the ammonia emissions from animal houses while biological air cleaning technologies remove more than 70% of the ammonia emissions and at the same time reduce the smell by 40-75%. Air cleaners can be applied on closed housing systems with controlled ventilation. Such systems are normally used for pig and poultry production but not used on normal dairy farms. It means that in most cases air cleaners cannot be used to reduce emissions from cattle housing systems. Hahne [26] in publication KTBL showed technical base of construction and exploitation of different filtering equipment.

MITIGATING MEASURES- MANURE STORAGE

In-storage Slurry acidification Technology

Acidification of slurry in storage tank happen by adding sulfuric acid to the slurry in the tank while the slurry is agitated. The acidification is normally taking place immediately before the slurry is brought to the fields for spreading as fertiliser, because of the slurry anyway needs agitation to be homogenised before spreading. The effect of acidification of slurry in storage tank on ammonia emission has not been verified scientifically; but, it is assumed that the effect is similar to that of slurry acidification during field spreading, 49% for cattle slurry, and 40% for pig slurry. The slurry acidification happen by adding approximately 2.5 litres of sulphuric acid per ton of slurry; however, with some variation up to 3 or more litres per ton slurry, dependent on the crop, the slurry quality and the envisaged pH in the acidified slurry [27].

Slurry separation and anaerobic digestion

Slurry separation is also good way of reducing ammonia emissions. Besides that, slurry separation decreases the manure storage capacity needs even up to 30% [21]. Tests conducted at universities in Germany have proved that anaerobic digestion of solid fraction leads to further GHG emissions reduction [28].

Holly conducted research where the effects of anaerobic digestion (AD), soli- liquid-solid (SLS), and AD+SLS on GHG and NH_3 emissions during manure storage through land application over nine months were evaluated [29]. The choice of separation technology should be coupled with a nutrient optimization strategies. According to acidification, there will be needed to ensure the environmental benefits of separating manure and/or digestion effluent [30]. In studies conducted by Carozzi [31] digestate was compared with urea to assess its effectiveness in sustaining maize growth and reducing odour and ammonia (NH_3) emissions during field application.

Coatings

The measures, most effective reducing gaseous emissions, besides slurry acidification, are coatings, and it is summarized in Table 3.

MITIGATING MEASURES-MANURE APPLICATION ON SOIL

Slurry injection

Types of slurry applicators mounted on slurry spreaders used in Poland and other countries:

- Applicators to bare soil: splash plate for arable lands. The slurry is broadcast spread with splash plate.
- Slurry injectors: shallow injection with open slot (with the depth of injection up to 5 cm) and deep injection with closed slot.

In-field slurry acidification technology

In field slurry acidification technology is very good alternative for slurry injection with comparative reduction of ammonia emission results. Danish producer of SAT (Slurry Acidification Technologies) "in-field" gives information about VERA (Verification of Environmental Technologies for Agricultural Production) certification results. During land application the slurry is continuously acidified by mixing concentrated sulphuric acid with slurry. The slurry acidification system is fully applicable in existing as well as new systems and can be mounted on any new or used slurry tanker and tractor that pulls it. The sulphuric acid has mixed with the slurry at the back of the tank using a static mixer, which has placed close to the slurry distributor. The static mixer contains solid turbulence elements that ensure effective mixing in just a few seconds. The VERA Verification Statement certifies that acidification during spreading has an ammonia emission reduction efficiency of 49 % when applied on cattle slurry, using band laying system for spreading on forage grass as reference [33].

Comparison of ammonia reducing effect between slurry injection and in-field acidification technique was performed.

TABLE 3. Ammonia emission reduction techniques for manure storages, their emission reduction levels and associated costs [32]

Techniques	Emission reduction (%)	Cost (€ per m^3 per year	Cost (€ per kg NH_3-N saved)
Tight lid	> 80	2–4	1–2.5
Plastic cover	> 60	1.5–3	0.5–1.3
Floating cover	> 40	1.5–3*)	0.3–5

CONCLUSIONS

Different techniques of ammonia emissions reduction from natural manure were discussed. Possibilities of decreasing of ammonia losses at different stages of manure management chain are as follows: slurry separation, digestion, slurry cooling, acidifying, covering of storages, slurry injection. The highest level of reduction (64%) with “in-house of slurry acidification using sulphuric acid,” technology and V-shaped slurry channels (70%) were obtained. Other techniques could be used in various combinations to obtain maximum ammonia reduction.

ACKNOWLEDGMENT

Present study conducted as part of the project BIOGAS&EE (acronym) financed by the National Centre for Research and Development within the BIOSTRATEG program, contract No BIOSTRATEG1 /269056/5/NCBR/2015 dated 11 August 2015.

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Persian Abstract

DOI: 10.5829/ijee.2019.10.01.07

چکیده

درباره روشهای کاهش انتشار آمونیاک و گاز گلخانه ای (GHG) از تولید دام مورد بررسی قرار گرفت. بسیاری از تکنیک ها هزینه های سرمایه گذاری بالا را با کاهش میزان انتشار گازهای گلخانه ای کاهش می دهند. در میان تمام روش های شناخته شده، موثرترین روش خنک کننده دوغاب و کاهش pH اسید است که باعث کاهش میزان انتشار آمونیاک می شود. هنگامی که ما درباره GHG صحبت می کنیم، هضم بی هوازی و جداسازی دوغاب، راه حل های مورد نظر است. با توجه به توسعه پایدار در تولید کشاورزی، نه تنها اثرات زیست محیطی، بلکه اقتصاد نیز مهم است.