Agronomy Research **17**(3), 797–805, 2019
https://doi.org/10.15159/AR.19.047

Most appropriate measures for reducing ammonia emissions in Latvia's pig and poultry housing

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Abstract. New goals of ammonia emissions reduction for each of EU Member State, including Latvia, were approved by the EU Directive 2016/2284/EU 'on the reduction of national emissions of certain atmospheric pollutants'. Agriculture sector, particularly livestock farming, is the main source of these emissions. Besides, the implementation of modern or intensive animal rearing/breeding technologies causes the increase of emissions in Latvia. Therefore, more effective ammonia abatement measures or techniques should be chosen for implementation in Latvia to reach the objectives. The description and benefits of such measures are provided in the guidelines and recommendations developed and approved by the United Nations Economic Commission for Europe (UNECE) and the European Commission. However, all of these recommendations are not applicable in Latvia. Therefore, the aim of research was to find most appropriate ammonia emissions abatement measures for pig and poultry farming in Latvia. The study was focused on the intensive pig and poultry farming, particularly animal housing. Evaluation or assessment of most appropriate ammonia emissions' reduction measures was conducted using an expert method. The results of the study indicate that it is possible to ensure reduction of ammonia emissions by comparatively simple and less expensive options that could be more or less easy implemented (e.g. ensuring cleanness in the livestock building, periodical removal of manure, covering of poultry litter or solid manure stockpiles with plastic sheeting, etc.). Even more effective reduction of ammonia emissions can be achieved by implementation of measures, which require significant investments, as well as additional operating costs.

Key words: ammonia, abatement measures, survey, housing.

INTRODUCTION

The environmental impact of modern or intensive farming, has led to a series of international protocols (e.g., Gothenburg Protocol), EU legislation, as well as national regulations. The new EU Directive 2016/2284 'on the reduction of national emissions of certain atmospheric pollutants' has adopted new ammonia emissions' reduction goals, which are based on the UN level agreement and the revised Gothenburg Protocol. Directive 2016/2284 sets out the commitments of each EU Member State to reduce emissions of five pollutants, including ammonia (NH_3) emissions (EC, 2016).

Two different timelines are considered: from 2020 to 2029, and from 2030 onwards; and the reduction goal is set by EU for each Member State as a percentage with 2005 emissions as its basis. For Latvia the reduction goal is equal for both periods: 1% for any year from 2020 to 2029; and 1% for any year from 2030 (EC, 2016), which is also approved on national level (Cabinet of Ministers, 2018).

It is recognised that agricultural sector has got the largest share of total amount NH_3 emissions in the world, Europe – 94%, as well as in Latvia – 86% (Frolova et al., 2017).

Moreover, many Member States reported the increase of emissions between 2014 and 2017 (Amann et al., 2017). In Latvia NH_3 emissions have increased substantially from 2005 until 2015 by 20.1%. The emissions from inorganic N fertilizer application have almost doubled (by 96.2%); from poultry (broilers) manure management, increased by 50%, and from livestock manure application grew by 19.2% (Melece, 2017). In 2015, 46% of Latvia's agricultural NH_3 emissions were generated from manure management (animal housing, grazing and manure storage), but 54% from other agricultural activities (i.e., application of manure and fertilizers) (Frolova et al., 2017).

The findings of our previous studies show (Frolova et al., 2017; Melece, 2017) that the implementation of modern or intensive agriculture, especially livestock rearing technologies and techniques, does not reduce, but increases the NH_3 emissions in Latvia. For instance, in the period from 2005 the NH_3 emissions rose by 80% in poultry farming. This is stressed by scientists that the adoption of proposed manure management technologies in practice is regionally diverse and still limited (Hou et al., 2018). Besides, it is outlined that the opinions of stakeholders are unknown and unexplored.

In terms of emission, including NH_3, control (i.e., monitor, reduce and mitigate) the EU has established regulations for large farms under the Directive 2010/75/EU, so called 'Industrial Emissions Directive'. For the intensive rearing of poultry or pigs, EU Decision 2017/302 of 15 February 2017 provided a recent update by establishing best available techniques (BAT) (EC, 2017). The Decision was supplemented by reviewed and updated BAT reference document (BREF) entitled 'Intensive Rearing of Poultry or Pigs' (Santonja et al., 2017). The BREF covers processes and activities in farms for the intensive rearing of poultry or pigs, as indicated in EU legislation: (a) with more than 40,000 places for poultry (b) with more than 2,000 places for production pigs (over 30 kg), or (c) with more than 750 places for sows.

Therefore, the aim of the research was to determine the most efficient and appropriate measures of ammonia emissions' reduction that could be implemented under Latvian circumstances in pig and poultry farming, particularly in housing.

MATERIALS AND METHODS

Preparation phase – review of ammonia emissions abatement measures

The literature review seeks to identify the main NH_3 emissions abatement (i.e., reduction) and mitigation measures or techniques for pig and poultry housing, which could be included in the questionnaire for further evaluation by experts or stakeholders. The principal materials used for literature review are as follows: different sources of literature, e.g., scholars' articles, research papers and the reports; as well as legislation, guidelines and recommendations of both international institutions (UN, UNECE) and EU (European Commission, EEA). The most promising NH_3 emissions' reduction measures for pig and poultry housing were indicated; and divided in three main groups:

(1) Measures that could be implemented in pig housing; (2) Measures that could be implemented in poultry housing; (3) Measures that could be implemented in the storage of pig and poultry manure.

Questionnaire and survey

For the evaluation of stakeholders' view the expert method was applied (Hand et al., 2001; Tan et al., 2006; Markovičs, 2009). For the evaluation of NH_3 emission abatement each technique or measure, the expert group of 10–15 stakeholders was created. The expert, who is well knowledgeable about the housing systems of particular livestock category, as well as manure management, was chosen. Therefore, in the each group of experts the following stakeholders were included: the leading specialists/experts of the Latvian Rural Advisory and Training Centre, the teachers and researchers from the Latvia University of Life Sciences and Technologies and specialists/managers from the largest livestock farms. Besides, there were an equal number of experts from each region of Latvia.

A pilot studies were carried out in order to clarify the questions and to increase knowledge and awareness of the experts about measure, issue and question. For this purpose, the introduction questionnaire was developed, in which not only the possible measures were mentioned, but there also additional information and characteristics of implementation of each abatement measure was given, as well as the NH_3 emissions' reduction potential was also presented. Besides, the experts were encouraged to add own proposals for improvement of the questionnaire. Hence, the thoughts or measures, which were dominant in the pilot, were also included in further study (development of the questionnaire).

The experts had to evaluate the necessity of implementation of every emission reduction measure using the following symbols: P – measures that need prior introduction, L – measures that can be implemented later, R – measures that can be rejected. Additionally, they had to mark the possible cost level and the necessity for the state support.

Accordingly the priority range of every emission reduction measure was determined and the measures that are suitable for the conditions of Latvia were stated. All emission reduction measures vary according to the character of their implementation possibilities in the livestock holdings. Therefore, they can be divided in three groups:

Group I - measures that do not require large capital investments, but it is mainly sufficient to improve the organisation of work;

Group II - measures the introduction of which requires reconstruction of the pig and poultry buildings, but the state support for it is not needed;

Group III - measures involving essential reconstruction of the pig and poultry housing facilities, and therefore the state financial support are needed.

Evaluation method of survey

Special methodology was developed for evaluation of the survey results and calculation of the possible reduction of emissions. For every answer of each question the number of positive answers was totalled and expressed as percents. After that the priority of each particular emissions reduction measure was calculated using following formula:

$$A = 1.0 \cdot N_P + 0.5 \cdot N_L \quad (1)$$

where A – evaluation of priority of implementation of the particular measure, in points; N_P – number of experts, expressed in %, who have evaluated the measure with P, %; N_L – number of experts, expressed in %, who have evaluated the measure as L, %; *1.0* and *0.5* – adopted or considered coefficients.

Applying such evaluation methods the obtained results can be from 0 to 100 points. If all experts evaluate a particular measure as prior, the total priority evaluation is 100 points. If, in turn, all experts consider that it is not necessary to implement a particular measure, the total evaluation is 0 points. Nevertheless, using this evaluation method in some cases, several measures have an equal number of points. Therefore, the additional information obtained from questionnaire, regarding the cost or investments for the measure's implementation, as well as the necessity of the state support was taken into account and was used as an additional factor, which was indicated by experts not in points but 'yes' or 'no'. Hence, unequivocal ranging can be obtained for all emissions' reduction measures.

Then the emission reduction coefficient was calculated for implementation of the particular measure (group of measures). For the calculation the following formula is used:

$$K_s = k_{s1} \cdot k_{s2} \cdots k_{sn} = \left(1 - \frac{S_1}{100}\right), \left(1 - \frac{S_2}{100}\right), \cdots \left(1 - \frac{S_n}{100}\right) \qquad (2)$$

where K_s – emission reduction coefficient; k_{s1}, k_{s2}... k_{sn} – emission reduction coefficients for every emission reduction measure (Table 1 and Table 2); S_1, S_2...S_n – amount of emission reduction for every particular measure at introduction, %.

RESULTS AND DISCUSSION

The results of the experts' questionnaire evaluation are summarised in the tables below. The NH_3 emission abatement measures are ranked according to received points. The results of reduction measure for pig housing are presented in Table 1.

Table 1. Emission reduction measures for pig farms

Abatement measure	NH_3 reduction, %**	Priority	
		Points	Group
Partly slatted floors (also improve animal welfare)	20–50%	89	I
Adding chemical or biological additives to slurry collected in canals and/or intermediate storages	up to 60%	87	I
Air scrubbing techniques	70–90%	83	III*
Dumping of liquid manure collection canals not less than 2 times per week	25%	83	I
Partly slatted floor and manure channel with slanted walls	up to 60%	78	II
Usage of vacuum (bath) system for collection of manure and transportation to the intermediate storage	up to 65%	66	II
Partly slatted floor and cooling manure surface	46–70%	66	III*
Replacement of reinforced grid for pen floors with metal grid or grid with plastic coating	15–20%	61	II
Reduction of indoor temperature in hot weather (also improve animal welfare)	up to 30%	55	I

* State support is needed to implement the measure; ** Bittman et al., 2014; UNECE, 2014; UNECE, 2015.

It can be seen that the experts not always have taken into account economic or investment costs of implementation of the measure. For instance, experts ranked as priority for pig housing (Table 1) the third most efficient measure 'Air scrubbing techniques', which is a more expensive measure (Table 4), not only for implementation expenses, but also operating costs are required. For example, the annualised investments for bioscrubbers in pig houses are around EUR 4–7 per animal place per year, and the annual operating costs vary between EUR 7.5 and EUR 9.5 per animal place per year. The system's lifetime is expected to be around 10 years (Santonja et al., 2017). Therefore, for Latvia this measure is included in priority Group III, as well as the necessity of state support is indicated.

Until now, the design of air scrubbers at pig and poultry housing facilities has mostly been based on the removal of NH_3. Optimising design and operation of air scrubbers should facilitate the simultaneous reduction of odour, nitrous oxide, methane and particulate matter in an efficient and cost-effective manner (Van der Heyden et al., 2015). Moreover, Dumont (2018) argues that in pig housing the chemical scrubber has no effect, whereas biological treatments can increase GHG emissions.

The research results regarding implementation priorities for the emission reduction measures in poultry housing are summarised in Table 2. Four emission reduction measures correspond to the priority Group I, but to Group II and Group III – one measure. It is important to outline that complying with the animal welfare regulations and implementation of comparatively simple measures, which does not require large financial investments, provides significant potential of emissions reduction.

Table 2. Emissions reduction measures in poultry housing

Abatement measure	NH_3 reduction, %**	Priority	
		Points	Group
Dry, well aerated house, the indoor temperature corresponds to animal welfare requirements	~70	100	I
Usage of nipple instead of bell drinkers	30%	100	I
Ventilated belts, manure removals more than two times a week	70%	71	II
In case of deep litter, usage of wood shavings and sawdust is advisable	~70%	67	I
Addition of aluminium sulphate (alum) to the litter, non-caged housing	70%	67	I
Drying of fresh manure on belts, removed 2–3 times a week, cage batteries	35–45%	57	III*

* State support is needed to implement the measure; ** Bittman et al., 2014; UNECE, 2014; UNECE, 2015.

The measures for reduction of NH_3 emissions that can be introduced in manure storage are summarized in Table 3. The content shows that in the storage of pig and poultry manure special attention should be paid to the covering of poultry litter or solid manure stockpiles with plastic sheeting or other covering material. Up to now, the special attention has not been paid to this measure in Latvia. Nevertheless, the experts have given 75 points for this measure. Besides, this measure is easy to be implemented and therefore it corresponds to the priority Group I. Appropriate reduction measure for storage of slurry or liquid manure in pig and poultry farms could be usage of chemical or biological additives, which has been highly ranked by experts. Nevertheless,

implementation of this measure is problematic due to the following issues: (i) necessity of comparatively large investments, well trained personnel and safety issues of chemicals; (ii) the lack of investigations and results regarding the impact of manure with low pH application on quality of soil. Accordingly, in our opinion this measure possibly could be implemented in the future.

Table 3. Measures for reduction of emissions in pig and poultry manure storage in farm

Abatement measure	NH_3 reduction, %**	Priority	
		Points	Group
Covering of poultry litter or solid manure with plastic covering or other synthetic sheeting	up to 60%	75	I
Usage of chemical or biological additives for slurry	up to 68%	75	I
Installation of light construction roofs over tall open tanks	up to 80%	70	III*
Replacement of lagoon slurry storages with covered tank or tall open tanks	30–60%	66	III*
Reduction of slurry storage surface (mirror surface) in new built storages	up to 60%	55	III*
Increase of litter stockpile height	up to 30%	55	II

* State support is needed to implement the measure; ** Bittman et al., 2014; UNECE, 2014; UNECE, 2015.

Despite that the results of presented study are indicated as very useful by involved and informed stakeholders, the latest guidelines, especially updated BAT reference document (BREF) 'Intensive Rearing of Poultry or Pigs' provides the findings of the latest studies, which are devoted to assessment of the various NH_3 emissions reductions or abatement measures and techniques, as well as applicability potential or current implementation limitations. The techniques and its applicability limitations of some emissions reduction options for pig housing are presented in Table 4, and for poultry housing in Table 5.

Table 4. Techniques and applicability limitations of some NH_3 emissions reduction measures for pig housing

Technique	Category	Applicability
In case of a fully or partly slatted floor: – A vacuum system for frequent slurry removal. – Slanted walls in the manure channel. – A scraper for frequent slurry removal.	All pigs	May not be generally applicable to existing plants due to technical and/or economic considerations.
V-shaped manure belts (in case of partly slatted floor).	Fattening pigs	May not be generally applicable to existing plants due to technical and/or economic considerations.
Air scrubbing techniques: acid scrubber or bioscrubber, or biotrickling filter.	All pigs	May not be generally applicable due to the high implementation cost. Applicable to existing plants only where a centralised ventilation system is used.

Source: Bittman et al., 2014; Santonja et al., 2017.

Table 5. Techniques and applicability limitations of some NH3 reduction measures for poultry housing in case of non-cage systems

Technique	Category	Applicability
Forced ventilation system and infrequent manure removal	Laying hens	Not applicable to new plants, unless combined with an air cleaning system
Manure belt or scraper (in case of deep litter with a manure pit).	Laying hens	Applicability to existing plants may be limited by the requirement for a complete revision of the housing system.
Forced air drying of manure or litter:		
– via tubes (in case of deep litter with a manure pit)	Laying hens	Only with sufficient space underneath the slats
– using indoor air (in case of solid floor with deep litter)	Broilers	Depends on the height of the ceiling.
– on manure belt (in case of tiered floor systems).	Broilers	Depends on the height of side walls.
Heated and cooled littered floor.	Broilers	Depends on possibility to install closed underground storage for water.
Manure belts (in case of aviary).	Laying hens Broilers	Applicability to existing plants depends on the width of the shed.
Air scrubbing techniques: acid scrubber or bioscrubber, or biotrickling filter.	Laying hens Broilers	May not be generally applicable due to the high implementation cost. Applicable to existing plants only where a centralised ventilation system is used.

Source: Bittman et al., 2014; Santonja et al., 2017

In order to calculate the efficiency of the measures of ammonia emission reduction included in each priority group formula (2) has been applied and emission reduction coefficients were obtained, which are presented in Fig. 1.

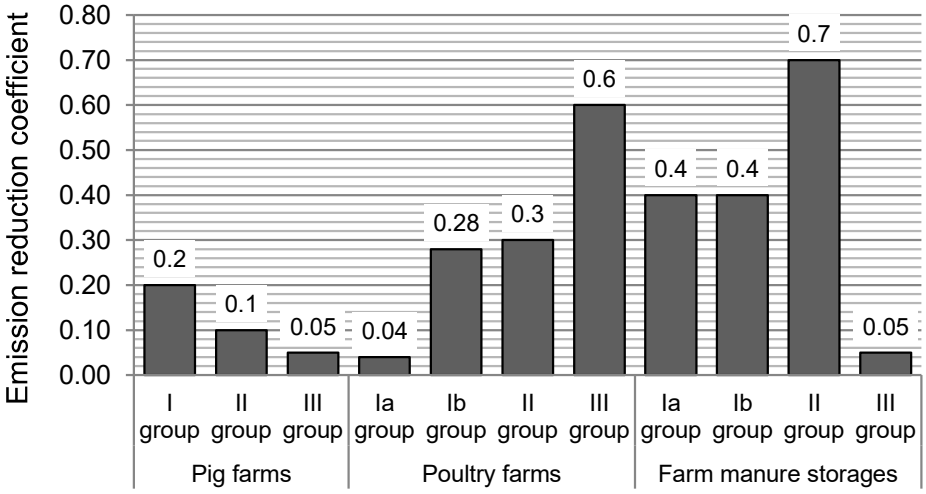

Figure 1. Estimated reduction coefficients for ammonia emissions by implementing measures included in different priority groups. Note: group Ia – deep litter poultry housing and storage of solid manure; group Ib – cage poultry housing and storage of slurry and liquid manure.

The presented in Fig. 1 coefficients have approximate value, because they are based on the maximum of emission reduction, which has obtained in the study. It could be concluded that a significant reduction in ammonia emissions can be achieved by implementation of Group I measures. Therefore, the measures of Group II and Group III should be implemented mainly in following cases: (i) receiving financial support from state managed funds, which are aimed to solve environmental issues; (ii) necessity to reconstruct or renovate the manure storage facilities or the particular farm buildings or animal houses in order to, for instance, improve the animal rearing/breeding technology, as well as for new farming activities. There are still problems, how to show the data of reduced emissions via the implemented measures in the National Inventory Report under the Convention on Long - Range Transboundary Air Pollution. For instance, despite the recent nature of the legislation, by 2015 almost 40% of the pig farms in the Netherlands had installed an air scrubber, although this is not yet reflected in the official emission inventory (Amann et al., 2017).

CONCLUSIONS

The reduction measures in pig and poultry farming should be aimed at larger or industrial farms, according to the latest EU and national regulations.

Notwithstanding, that involvement of various stakeholders (i.e., experts and representatives of farmers) in the evaluation of emissions abatement techniques is advisable, in some cases, they paid less attention to the economic aspects (investments, operating costs) of implementing, for example, air scrubbing techniques.

The implementation of a balanced combination of measures with comparatively low costs, for example, ensuring cleanness in the livestock building, periodical removal of manure, covering of poultry litter or solid manure stockpiles with plastic sheeting, etc., could effectively reduce overall ammonia emissions.

However, more effective abatement technologies and techniques, for example, air scrubbing techniques, replacement of lagoons for slurry storage with covered tanks, drying of litter on belts, etc., could be implemented mainly during reconstruction of farms and farm manure storages or during construction of new buildings/ animal houses. Moreover, implementation of these measures should receive some support by the state.

There is a lack of methodology or guidelines for quantification of the reduced amount of ammonia emissions for a large number of reduction measures, which are recommended by international (UNECE) and EU institutions, and probably could be successfully implemented. It means that the reductions at present cannot be represented in the national reports, particularly in Latvia.

ACKNOWLEDGEMENTS. The paper was partially supported by the project No 4 “Challenges and Solutions of Latvian State and Society in an International Framework - INTERFRAME-LV” within the National Research Program “Challenges and Solutions of the Latvian State and Public in the International Context” (No VPP-IZM-2018/1-0005).

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