ANNALS OF THE POLISH ASSOCIATION OF AGRICULTURAL AND AGRIBUSINESS ECONOMISTS

received: 25.03.2019
acceptance: 11.04.2019
published: 03.06.2019
JEL codes: Q15, Q53

Annals PAAAE • 2019 • Vol. XXI • No. (2)

DOI: 10.5604/01.3001.0013.2071

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AMMONIA EMISSION FROM ANIMAL PRODUCTION IN POLAND ON A REGIONAL SCALE[1]

Key words: ammonia emissions, animal production, regions

ABSTRACT. The aim of the study was to present ammonia emissions from animal production on a regional scale in 2016. Emission estimates in particular regions were based on methodology developed by EEA in 2016 and applied in Poland by The National Centre for Emissions Management (NCEM). The conducted analyses were based on the size of livestock population, farming system and emission factors at every stage of manure management. The analysis showed substantial spatial differentiation of ammonia emissions from animal production. Voivodships that accounted for the biggest share in emissions from cattle farming were as follows: Mazowieckie, Podlaskie and Wielkopolskie. Estimated emissions in these voivodships amounted to: 47.4, 32.8 and 21.7 Gg NH_3, respectively. The highest levels of ammonia emissions from pig production were identified in the region of Wielkopolska. Ammonia emissions in this voivodship amounted to 16.2 Gg NH_3. The Wielkopolska region is also distinguished by the highest ammonia emissions from poultry production. The emissions equaled 11.4 Gg NH_3 and accounted for 24.1% of total emissions in this region. The realization of reduction commitments for ammonia imposed by the NEC Directive depends on the introduction of a set of changes in livestock production: regarding the housing method, animal nutrition, fertilizer storage and application as well as dissemination of good agricultural practices aiming at ammonia emission reduction.

INTRODUCTION

When the Directive (EU) 2016/2284 of the European Parliament and Council on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC (so-called NEC Directive) came into force on 31 December 2016, it resulted in the extension of Member States' obligations concerning the emission reduction of substances covered by the Directive by the year 2030 [Official Journal UE, L 344/1]. One of the five pollutants covered by the national emissions limits in the NEC Directive is ammonia, emitted from manure and mineral nitrogen fertilization. Poland has been obliged to reduce its ammonia emissions by 1% each year from 2020 to 2029 and by 17% in total by the year 2030 in comparison to 2005.

Farm animals are useful to society in many ways. On the one hand, there is a steadily growing demand for dairy, meat and egg products, on the other, there is also a need and much pressure to prevent or counteract the adverse effects of agricultural production

[1] The study was carried out as part of the task of the 2.6 Multiannual Programme 2016-2020.

(animal production in particular) on the environment. Continuous attempts are made to turn animal production systems into more environmentally friendly ones. According to the National Centre for Emissions Management (NCEM), agriculture is the main source of ammonia emissions (more than 97%), where consumption of mineral nitrogen fertilizers accounts for 17% of emissions, while the remaining 83% come from animal production [KOBiZE 2018].

NH_3 emissions mainly come from nitrogen present in animal excrements. NH_3 emissions from animal production are directly linked to the type, number and genetic potential of livestock, management and feeding method, animal housing system and manure management. Ammonia is emitted at all stages of production: livestock housing, storage, processing and fertilization, as well as excretion during grazing. Nitrogen losses due to ammonia emissions in farm buildings are estimated at 10-20% depending on the farming system and type of animals [Marcinkowski 2010]. The highest emissions from livestock housing are recorded for pigsties and henhouses, which account for 25% of nitrogen contained in excrements [Pietrzak 2012]. Ammonia losses from natural fertilizers during storage depend on the type and composition of the fertilizer, storage time, meteorological conditions (temperature and wind speed) and storage method. Average nitrogen losses from natural fertilizers during storage are estimated to be at 20-50%, whilst nitrogen losses in the form of ammonia from these fertilizers applied on agricultural land range from 20 to 30% [Pietrzak 2006].

Due to the above, in many EU Member States, as in Poland, measures are taken to improve regulations concerning manure management with the aim to reduce ammonia emissions. Since practices aiming at emission reduction apply to individual farms, the successful implementation of such actions depends on the effective involvement at both a national and local level.

The aim of this work is to present the spatial distribution of ammonia emissions from animal production, which constitutes the largest share of ammonia emissions from Polish agriculture.

MATERIAL AND METHODS

Ammonia emission estimation for specific regions was based on methodology published by the European Environment Agency (EEA), with new guidelines updated in 2016 [EMEP/EEA 2016].

Ammonia emissions from animal production are estimated based on the size of the livestock population. In the analysis, data on livestock size according to voivodships were used and acquired from 2016 national statistics of the Central Statistical Office (CSO) (Table 1). Due to a lack of data on farming systems at a regional scale, national indicators of manure (animal excrements) management used by NCEM were adopted for this purpose (Table 2). Ammonia emission estimations are based on the amount of nitrogen excreted by each animal category and emission factors specified for each stage of manure management (Table 3). To calculate the amount of nitrogen in livestock excrements (Nex) used for estimating NH_3 emissions for cattle, sheep, pigs and poultry, standard nitrogen contents in faeces and urine were adopted for each animal category. They were defined based on standard feed amount

Table 1. Size of livestock population by voivodships in 2016

Voivodships	Size of population [thous. head]							
	dairy cows	other cattle	sows	other pigs	sheep	layers	broilers	other poultry
Dolnośląskie	41	62	29	168	12	2,398	2,217	496
Kujawsko-pomorskie	160	342	105	1,049	9	1,641	7,340	660
Lubelskie	139	223	45	513	14	1,611	3,312	1,266
Lubuskie	28	47	11	137	4	1,160	2,858	1,274
Łódzkie	183	273	73	1,007	12	2,606	8,327	941
Małopolskie	86	95	21	157	76	2,477	1,551	284
Mazowieckie	479	592	60	857	6	10,317	18,878	2,270
Opolskie	43	79	32	346	3	630	2,024	117
Podkarpackie	50	39	17	154	18	1,953	2,615	397
Podlaskie	437	509	26	282	19	1,036	6,799	944
Pomorskie	68	138	66	683	15	1,571	3,212	272
Śląskie	45	77	21	227	14	2,553	3,975	248
Świętokrzyskie	58	108	22	189	5	1,028	4,054	529
Warmińsko-mazurskie	193	249	40	414	9	955	2,831	3,850
Wielkopolskie	283	714	256	3,580	18	15,425	12,963	4,999
Zachodniopomorskie	39	58	28	247	5	990	4,509	196
Polska	2,332	3,607	854	10,012	239	48,350	87,464	18,742

Source: own study based on CSO data [GUS 2017]

and digestibility [Kopiński 2017]. Nex for dairy cattle increases over time depending on the milk yield per cow. The highest, 83 kg N unit per year was calculated for cows with a milk production of above 4,500 l per year and has been used since 2011. The national Nex indicators used in the estimates are consistent with those published by the UN Economic Commission for Europe [UNECE 2014].

To estimate ammonia emissions from natural fertilizers, Tier 2 methodology was used (mass flow approach), which is also applied by NCEM to calculate air pollutant emissions (including ammonia) covered by the reports to the UN Convention on Long-range Transboundary Air Pollution (LRTAP) and for the purposes of national statistics and EU requirements.

Table 2. Animal housing system

Animals	Animal housing system	% of population
Dairy cows	no bedding	0.1053
	bedding	0.7917
	pasture	0.1030
Other cattle	no bedding	0.0506
	bedding	0.8294
	pasture	0.1200
Pigs	no bedding	0.2432
	bedding	0.7568
	pasture	0
Sheep	no bedding	0
	bedding	0.5951
	pasture	0.4049
Poultry	no bedding	0.1109
	bedding	0.8891
	pasture	0

Source: own study based on NCEM data [KOBiZE 2018]

Table 3. Size of indicators adopted by NCEM under Tier 2

Livestock class	Proportion of TAN	N added in bedding [kg/animal/year]	Housing period [days]	Excreta on yards [%]	Ammonia emission indicator EF NH_3	
					house, slurry	house, solid manure
Dairy cows	0.6	6.00	155	25	0.2	0.19
Other cattle	0.6	2.00	155	10	0.2	0.19
Sows	0.7	2.40	365	0	0.22	0.25
Other pigs	0.7	0.80	365	0	0.28	0.27
Sheep	0.5	0.08	30	2	-	0.22
Layers	0.7	0.00	365	0	0.41	0.41
Broilers	0.7	0.00	365	0	0.41	0.28
Turkeys	0.7	0.00	365	0	-	0.35
Ducks	0.7	0.00	365	0	-	0.24
Geese	0.7	0.00	365	0	-	0.57
	Ammonia emission indicator EF NH_3					
	yard	storage, slurry	storage, solid manure	application, slurry	application, solid manure	pasture grazing
Dairy cows	0.3	0.2	0.27	0.55	0.79	0.10
Other cattle	0.53	0.2	0.27	0.55	0.79	0.06
Sows	0	0.14	0.45	0.29	0.81	0,25
Other pigs	0.53	0.14	0.45	0.40	0.81	0.00
Sheep	0.75	-	0.28	-	0.90	0.09
Layers	-	0.14	0.14	0.69	0.69	-
Broilers	-	0.14	0.17	0.66	0.66	-
Turkeys	-	-	0.24	-	0.54	-
Ducks	-	-	0.24	-	0.54	-
Geese	-	-	0.16	-	0.45	-

Source: EMEP/EEA [2016]

RESULTS

The conducted analysis showed considerable differences in the spatial distribution of ammonia emissions from animal production. The volume of natural fertilizer production, and consequently, nitrogen flows depend on the structure and population density of livestock as well as the housing system. The total ammonia emission from animal production amounted to 208.43 Gg. Calculated per 1 ha of agricultural land in good culture, it came to 15 kg NH_3. The highest rates were calculated for the following voivodships: Wielkopolskie, Mazowieckie and Podlaskie (Figure 1). Emissions estimated for these voivodships amounted to: 47.4, 32.8 and 21.7 Gg $NH_{3,}$ respectively. Concentration of animal production in the Wielkopolskie

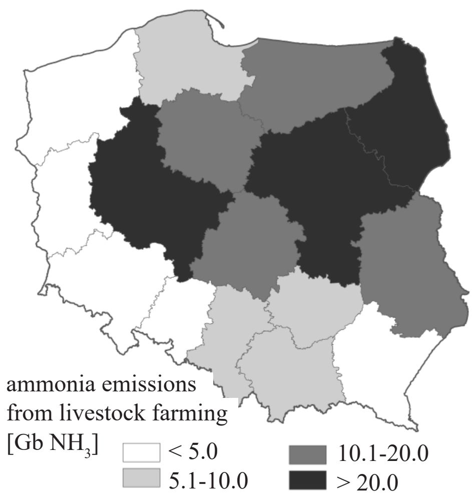

Figure 1. Regional differentiation of ammonia emissions from livestock production

Source: own study

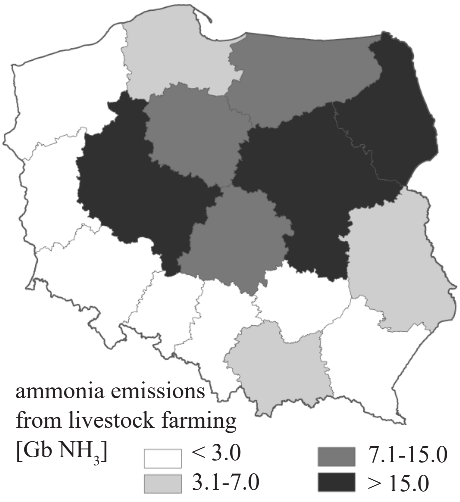

Figure 2. Regional differentiation of ammonia emissions from cattle production

Source: own study

and Podlaskie regions resulted in a higher emission intensity per 1 ha of agricultural land in good culture, which amounted to 28 and 20 kg NH_3 ha-1, respectively. Slightly smaller ammonia emissions, ranging from 11.5 to 16.7 Gg, were identified in the regions of Lubelskie, Warmińsko-Mazurskie, Łódzkie and Kujawsko-Pomorskie voivodeships.

Research also showed regional differentiation in shares of particular animal categories in total ammonia emissions. Total ammonia emissions from cattle were estimated at 106.4 Gg. The largest share was represented by cattle production in the Mazowieckie, Podlaskie and Wielkopolskie voivodeships (Figure 2). In the Mazowieckie voivodeship it amounted to 20.1 Gg NH_3, which constituted 61.3% of total emissions in this region, whilst in the Podlaskie voivodship it amounted to 18.0 Gg, i.e. 82.9% of total emissions. Both voivodships are characterised by the highest cattle stocking density in Poland. Thanks to a large acreage of grassland, there is also a well-established production of dairy cattle.

The highest ammonia emissions from pig production were estimated for the region of Wielkopolska, where it amounted to 16.2 Gg (Figure 3). Significantly lower emission rates were identified for the Kujawsko-Pomorskie, Łódzkie, Mazowieckie and Pomorskie voivodships, falling within the range of 4.0-6.1 Gg NH_3. The highest ammonia emissions from poultry production were identified for the Wielkopolskie voivodship (Figure 4) and amounted to 11.4 Gg NH_3, constituting 24.1% of total emissions in this region. Slightly lower emissions were estimated for the Mazowieckie voivodship (8.0 Gg NH_3).

The area structure of agricultural holdings had a definite impact on the differentiation of ammonia emissions from animal production [Bieńkowski 2010]. In large farms the scale of livestock production is greater.

Bearing in mind the ammonia emission commitments imposed by the NEC Directive, it will be necessary to reduce emissions mostly in voivodships with well-established animal production and to propose actions aiming at fulfilling such commitments.

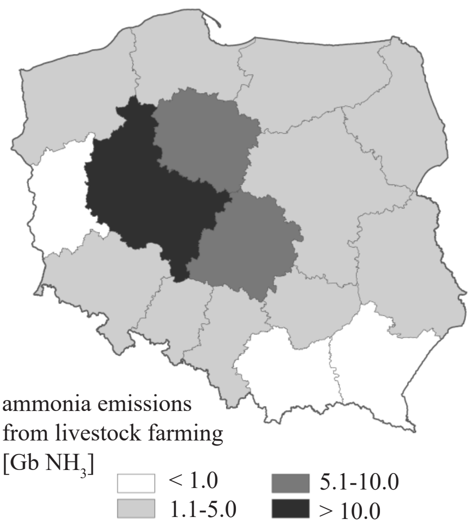

Figure 3. Regional differentiation of ammonia emissions from pig production

Source: own study

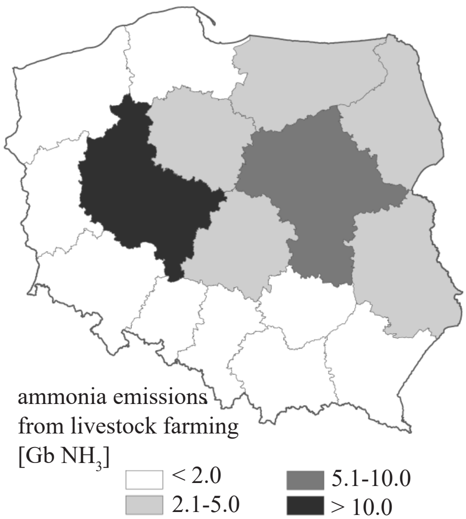

Figure 4. Regional differentiation of ammonia emissions from poultry production

Source: own study

When it comes to natural fertilizers, practices reducing ammonia emission are recommended, such as changing the strategy of feeding farm animals by introducing balanced feed rations determined on the basis of nutritional requirements of livestock and adjusted to specific needs of different animal categories and stages of the production cycle. Such practices reduce the amount of nitrogen in excrements.

The reduction of ammonia emissions in livestock housing may be achieved by limiting the surface area of natural fertilizers and the time they lie in the open air. Inside buildings, it is recommended to reduce the area contaminated with natural fertilizer, maintaining clean paths and paddocks for animals, and removing urine quickly. It is also important to remove ammonia from the air released from inside buildings. A very efficient and highly recommended method is using biofilters.

In order to reduce ammonia emissions, it is essential to improve conditions and technologies used for the storage of natural fertilizers. Ammonia emissions from manure storage can be reduced by: storing in layers and compressing stockpiles of manure, covering manure heaps, minimizing the storage area by increasing the height of stockpiles, maintaining the temperature inside the heap below 50^0C as well as mounting roofs above the heap to remove rainwater. Excess of rainwater could otherwise lead to a leak of nutrients from the manure heap. The best storing method for solid natural fertilizers is to keep them in impermeable containers or specially designed facilities. The reduction of ammonia emissions from liquid fertilizers during their storage may be realized by preventing its contact with open air. To this end, roofs or lids made of plastic should be mounted above containers, or the content should be protected using natural or artificial insulation layers (e.g. exclay).

Among recommended low-emission practices, there are as well application methods. The greatest ammonia losses occur in the first hours after the application of natural fertilizers. In case of liquid fertilizers, covering the slurry spread on the field immediately will result in emission reduction by 70-90%. Covering after 4 hours reduces emissions by 45-65%, and after 24 hours by 30% [Faber, Jarosz 2018]. Therefore, it is recommended to combine the application of slurry with immediate ploughing. A very effective method of reducing ammonia emissions from slurry is direct application into the soil (by injection) or bandspreading, thus reducing the area exposed to the air and increasing transfer of nutrients to the soil. Shallow injection of slurry (4-6 cm) into open slots reduces ammonia emissions by 70%, and into closed slots by 80%, whilst deep injection (10-30 cm) results in ammonia emission reduction by 90%. In case of manure, the best method is to cover it with soil after application. Immediate incorporation by ploughing results in ammonia emission reduction by 60-90%. The effectiveness of this method decreases over time. Covering the manure 4 hours after application reduces emissions by 45-65%, and after 24 hours by 30% [Faber, Jarosz 2018].

The above examples of practices do not exhaust all the possible measures reducing ammonia emissions from agricultural activity. They do however show a wide scope of possible actions that could be taken in order to successfully reduce emissions from this sector.

CONCLUSIONS

Ammonia emission reduction is considered a necessity both at a European and international level. The conducted analysis showed a considerable spatial differentiation of ammonia emissions from animal production. The following voivodships represent a dominant share in ammonia emissions from cattle production: Mazowieckie, Podlaskie and Wielkopolskie. The latter is also responsible for the biggest share of ammonia emissions from pig and poultry production.

The realization of reduction commitments for ammonia, imposed by the NEC Directive, depends on the introduction of a set of changes in livestock production, regarding housing method, animal nutrition, fertilizer storage and application. It will not only require considerable financial contributions to modernize Polish agriculture, especially when it comes to implementing new functional solutions in livestock housing and agricultural machinery, but also increased educational efforts and dissemination of good agricultural practices aiming at ammonia emission reduction.

BIBLIOGRAPHY

Bieńkowski Jerzy. 2010. Regional differentiation of ammonia emission in polish agriculture in the years 2005-2007. *Fragmenta Agronomica* 27 (1): 21-31.

Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. Official Journal of the European Union, L 344/1, 17.12.2016.

EMEP/EEA. 2016. *EMEP/EEA air pollutant emission inventory guidebook* 2016. Copenhagen: European Environment Agency.

Faber Antoni, Zuzanna Jarosz. 2018. Agricultural practices to reduce ammonia emissions. *Studies and Reports IUNG-PIB* 56 (10): 35-44.

GUS (CSO – Central Statistical Office). 2017. *Farm animals in 2016*. Warszawa: GUS.

KOBiZE (NCEM – National Center for Emissions Management). 2018. *National balance of emissions of SO_2, NOx, CO, NH_3, NMLZO, dust, heavy metals and TZO for the years 2015-2016*. Warszawa: IOŚ-PIB, Krajowy Ośrodek Bilansowania i Zarządzania Energiami.

Kopiński Jerzy. 2017. *Gross nitrogen balance agro environmental impact indicator of agriculture on the environment*. Puławy: IUNG-PIB.

Marcinkowski Tadeusz. 2010. The emission of gaseous nitrogen compounds from agriculture. *Water-Environment-Rural Areas* 10 (3):175-189.

Pietrzak Stefan. 2012. *Priority measures in the area of reduction of nitrogen and phosphorus losses from agriculture in the aspect of water quality protection.* Falenty: Institute of Technology and Life Sciences.

Pietrzak Stefan. 2006. Inventory method for ammonia emissions from agricultural sources in Poland and its practical application. *Water-Environment-Rural Areas* 6 (1): 319-334.

UNECE (United Nations Economic Commission for Europe). 2014. *Guidance document on preventing and abating ammonia emissions from agricultural sources.* Economic Commission for Europe. ECE/EB.AIR/120, 7 February 2014.

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EMISJA AMONIAKU Z PRODUKCJI ZWIERZĘCEJ W POLSCE W SKALI REGIONALNEJ

Słowa kluczowe: emisja amoniaku, produkcja zwierzęca, regiony

ABSTRAKT

Celem badań było przedstawienie emisji amoniaku z produkcji zwierzęcej w skali przestrzennej. Oszacowanie emisji amoniaku w poszczególnych regionach wykonywano na podstawie metodyki opublikowanej przez EEA w 2016 roku i stosowanej w Polce przez KOBiZE. Analizy wykonano na postawie wielkości pogłowia zwierząt gospodarskich, systemów ich utrzymania oraz współczynników emisji na każdym etapie gospodarowania nawozami naturalnymi. Przeprowadzona analiza wykazała znaczne przestrzenne zróżnicowanie emisji amoniaku z produkcji zwierzęcej. Dominującą rolę w emisji amoniaku z chowu bydła miały województwa: mazowieckie, podlaskie i wielkopolskie. Oszacowane emisje wyniosły odpowiednio: 47,4, 32,8 i 21,7 Gg NH_3. Najwięcej emisji amoniaku z produkcji trzody chlewnej odnotowano w regionie wielkopolskim. Emisja amoniaku w tym województwie wyniosła 16,2 Gg NH_3. Region wielkopolski wyróżnia się także największą emisją amoniaku z produkcji drobiu. Emisja ta wynosiła 11,4 Gg NH_3 i stanowiła 24,1% całkowitej emisji w tym regionie. Osiągnięcie zobowiązań dotyczących ograniczania emisji amoniaku wskazanych w dyrektywie NEC będzie wymagało wprowadzenia zmian w produkcji zwierzęcej i upowszechniania dobrych praktyk rolniczych, skutecznie wpływających na redukcję emisji amoniaku.

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